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WIRE ROPE TRANSPORTATION

IN ALL ITS BRANCHES.

Wire-Rope Tramways,
Hoist-Conveyors,
Mine Haulage Plants
AND
POWER TRANSMISSIONS.

THE TRENTON IRON CO.,
TRENTON, NEW JERSEY, U. S. A.

1897.

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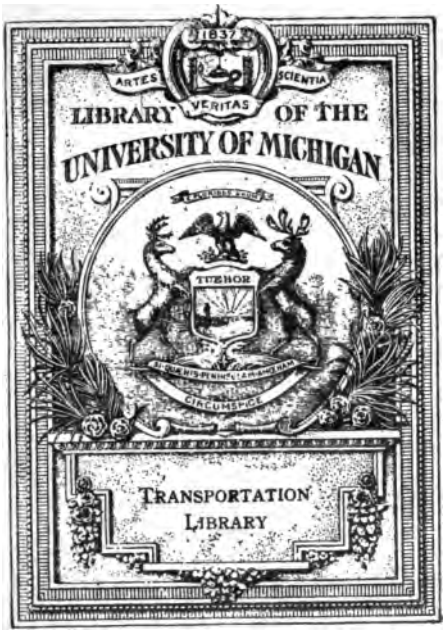

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Wire Rope Transportation

IN ALL ITS BRANCHES.

Wire Rope Tramways,

OF

THE "BLEICHERT," "ROE" AND "ACME" PATENT SYSTEMS;

PATENT HOIST-CONVEYORS,

For Quarries, Dam Building, Open Cut Work, &c.;

WIRE ROPE OUTFITS

For Shafts, Inclined Planes, Surface and Underground Haulage Plants, &c.

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Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for La Gran Fundicion National Mexicana, Santa Catarina, Mexico. Length of line, 8,650 feet; daily capacity, 100 tons.

Wire Rope Tramways.

Introductory Remarks.

Wire rope tramways have been long recognized as a means of cheap transportation. Their advantages as feeders to established systems of railroad or water communication, and their low cost of construction, especially in mountainous localities, where any kind of surface road would be scarcely practicable, except with long and costly detours, is well understood. Even where there are few or no natural obstacles to the building of a surface road, wire rope tramways possess many advantages to commend them. They are seldom affected by fire, wind or flood; the service is entirely free from surface traffic, snow or other obstructions; stoppages for repairs are rare, and operating expenses are relatively low. The terminals are so arranged that the material transported can be delivered at the exact spot where it is needed, thus saving all expense of re-handling. This could not be done with a surface road, since, even if the cars are brought close to the point at which the material is required, there would still be a further expense for unloading, besides the cost of switching.

We manufacture three distinct systems of aërial transportation, all protected by patents, the "Bleichert," the "Acme," and the "Roe," the relative merits of which are herein set forth. The first two belong to that type in which the loads are suspended from stationary rail cables, and are propelled by means of an independent traction rope; and the latter to the single rope type in which an ordinary endless rope not only carries the pendant loads but is also the means of propulsion.

We are also prepared to manufacture equipments for the special types of wire rope tramways, cable hoist-conveyors, and surface haulage plants, described in the following pages, and others specially designed to meet extraordinary conditions.

Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Bunker Hill and Sullivan Mining and Concentrating Company, Kellogg, Idaho. Length of line, 9,000 feet; daily capacity, 400 tons.

The Bleichert System

OF

Wire Rope Tramways.

The "Bleichert" system of wire rope tramways is most complete in all its appointments; it can be operated in any locality; it is well adapted to the transportation of all kinds of materials, and is especially recommended for heavy service, and where steep grades and long spans occur. Every detail has been thoroughly worked out and proved by actual practice. The materials used are of the strongest and best, and the workmanship first class in every respect. All parts of the machinery are made to standard gauges, so that repairs can be made promptly and cheaply. The general design is such as to make the action of the tramway as nearly automatic as can be, so that but little labor is required in the operation of these lines. The cars can be raised or lowered at any terminal or intermediate station by our special hoists, from one level to another, or from one floor to another, in a warehouse or factory for instance, and upon arriving at the desired elevation or floor, can be conveyed by our suspended or shunt rails to any point for loading or unloading. Scales are furnished of special design for weighing the loaded cars, or counters which will automatically register the number transported.

By means of specially designed cars the buckets can also be transferred from the hanging rail to surface tracks and taken directly to the working faces of the mine or quarry, as the case may be, brought back and sent over the line, without re-handling of the material.

The "Bleichert" system permits of the introduction of intermediate loading stations at any point, which may be movable or permanent structures as desired. It is also well adapted to the loading and unloading of vessels (see illustrations on pages 20 and 22).

Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Bunker Hill and Sullivan Mining and Concentrating Company, Kellogg, Idaho. Showing span of 1173 feet across the town of Wardner.

Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for La Gran Fundicion National Mexicana, Santa Catarina, Mexico. Length of line, 8,650 feet; daily capacity, 100 tons.

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The Bleichert System

OF

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The "Bleichert" system of wire rope tramways is most complete in all its appointments; it can be operated in any locality; it is well adapted to the transportation of all kinds of materials, and is especially recommended for heavy service, and where steep grades and long spans occur. Every detail has been thoroughly worked out and proved by actual practice. The materials used are of the strongest and best, and the workmanship first class in every respect. All parts of the machinery are made to standard gauges, so that repairs can be made promptly and cheaply. The general design is such as to make the action of the tramway as nearly automatic as can be, so that but little labor is required in the operation of these lines. The cars can be raised or lowered at any terminal or intermediate station by our special hoists, from one level to another, or from one floor to another, in a warehouse or factory for instance, and upon arriving at the desired elevation or floor, can be conveyed by our suspended or shunt rails to any point for loading or unloading. Scales are furnished of special design for weighing the loaded cars, or counters which will automatically register the number transported.

By means of specially designed cars the buckets can also be transferred from the hanging rail to surface tracks and taken directly to the working faces of the mine or quarry, as the case may be, brought back and sent over the line, without re-handling of the material.

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Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Bunker Hill and Sullivan Mining and Concentrating Company, Kellogg, Idaho. Showing span of 1173 feet across the town of Wardner.

The chart of details at the end of the chapter gives a general idea of a few of the various applications to which this system of tramways is adapted, all of which are taken from lines actually constructed and in constant operation.

The track cables are of special construction, and known as the "patent interlocked cable," from the fact that the outer wires are of such shape that they interlock with each other, as shown in the accompanying illustration, presenting a smooth surface, and yet possessing sufficient flexibility to be shipped in coils. This cable gives the highest degree of service with minimum wear on the carriage wheels. It is made of steel wires, in lengths of from 400 to 500 feet, joined by patented couplings (see Fig. 116, page 145).

Patent Interlocked Track Cable.

The carrying cables being stationary, can be locally graduated to the strains they have to bear, not only in the case of long spans, but also on steep grades, where these cables must sustain, in addition to the ordinary working strain, a further strain due to the weight of the cables themselves. It is simply necessary to make the portions at these points strong enough to bear the extra strain, and not the whole length of the cable. The cable for the empty cars moreover does not necessarily require to be as strong as the cable for the loaded cars, and it is therefore made only strong enough for the work it has to perform.

Stationary track cables possess the great advantage of relieving the traction rope to a great extent of the weight of the loads and its own weight as well, so that on comparatively level lines the strain upon it is but little more than the tractive force required to move the loads. Upon slopes, however, the weight of the loads is shared to a certain extent by both carrying cable and traction rope, the amount borne by each depending on the inclination; the steeper the inclination

Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Royal Coal and Coke Company, Prince, West Va. Length of line, 2,800 feet; daily capacity, 800 tons.

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Stationary track-cables possess the great advantage of relieving the traction rope to a great extent of the weight of the loads and its own weight as well, so that on comparatively level lines the strain upon it is but little more than the tractive force required to move the loads. Upon slopes, however, the weight of the loads is shared to a certain extent by both carrying cable and traction rope, the amount borne by each depending on the inclination; the steeper the inclination

Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Royal Coal and Coke Company, Prince, West Va.; showing span across New River

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the greater the strain on the traction rope and the less that on the carrying cable, and *vice versa*. It is important, therefore, in estimating upon any lines to know what the grades are. A further advantage derived from the use of stationary traek-cables is due to the high tension to which these are stretched, thus securing to the loads a comparatively direct path ; in other words they are subject to less fluctuations of rise and fall or wave motion than in single rope lines, since in the latter the deflections for similar loads must necessarily be greater to correspond with a practical safe working tension, and the double duty the rope has to perform of supporting and moving the loads. The strain due to the moving loads, therefore, in the "Bleichert" system, is not only less, but being borne by two ropes instead of one, the wear and tear in consequence are very much less. For this reason also, and owing to the greater strength of the carrying cables, the "Bleichert" system is adapted to the transportation of much heavier loads than is practicable in any kind of single rope tramway.

Our practice is to lay out the line of the track cables very carefully for a certain safe working tension, and erect the supports to this line, the cables being actually stretched to a somewhat lower tension, so that there may be no possibility of their rising out of the saddles upon which they rest.

The spacing of the supports depends altogether on the contour of the ground. On level stretches the distance is from 150 to 200 feet, according to the capacity of the line. Where the contour is much broken, as exemplified in the profile of the United Concentration Company's line, at Monte Cristo, Washington (see sheet of profiles), the distances between the supports vary very much, being closer on the ridges and wider apart in the valleys. Where the ridge is a very sharp one, we introduce what are termed "rail stations," which consist of a series of bents, from 15 to 20 feet apart, supporting rails which overlie the track cables, and save the latter from undue wear at these points. In crossing ravines, valleys, and rivers, on the other hand, clear spans have been made up to 2,200 feet, one of this length occurring in the line of the Silver Lake Mining Company, Colorado.

If the line is over a mile in length, it is advisable to apply tension to the carrying cables at intermediate points, on account of the saddle friction, and special stations are introduced for this purpose. The

carrying cables are parted here, and the ends either rigidly anchored or counterweighted. The cars pass from one section of the cable to the next by means of intervening rails, so that no interruption occurs in the continuity of the track.

For short lines and light service, a single line of carrying cable may be used. In such cases, convenient turnouts are arranged along the line, and the trains of cars so spaced as to pass at these turnouts. The only advantage possessed by these single track lines is their comparative cheapness of installation; the cost of operating is about the same as those of the regular construction.

The cars are attached to the traction ropes by means of patent grips of such construction that upon arriving at either terminal or other station they are detached automatically, the carriages leaving the carrying cables and running on elevated rails supported by the structure of the station.

Two styles of grips are made: one depending simply on frictional contact to hold the cars, the other of a positive nature, designed to straddle lugs, secured to the traction rope at intervals regulated by the amount of material to be transported, and used where steep grades occur. These lugs are made in halves, and applied in such a way that they can be readily replaced by new ones, or moved to other points along the traction rope, as circumstances may require.

Intermediate loading stations are so designed as not to interfere with the through traffic. Horizontal bends, however, require stations at which all cars must be detached, and passed by hand from one section to the next, and for this reason they are undesirable unless occurring at points of loading or discharge.

The advantages of the "Bleichert" system of Wire Rope Tramways may be summed up as follows:

1st.—*It is adapted to the heaviest traffic.* Loads up to a ton in weight may be carried, and from 80 to 100 tons per hour transported, which is not possible with any kind of single-rope tramway.

2d.—*A speed of 3 to 4 miles per hour can be maintained*, which is not practicable in single-rope lines of the Hallidie and Huson types, not only on account of the trouble due to the dropping of the rope from the shallow supporting sheaves, but mainly on account of the fact that the buckets are permanently attached to the rope, so that

their loading and discharge must be effected while they are in motion.

3d—*The number of cars required for a given service is less than on other lines.*

4th.—*The steepest grades can be surmounted without difficulty.*

5th.—*Less power is required, or more developed, as the case may be, than in any other system.* This is due to the fact that the traction rope, instead of being loaded down by the cars, as in single rope lines, is itself supported by them to a certain extent, as already explained. In other words, a "Bleichert" tramway will work by gravity on a lesser grade for a given output than any other. For instance, the line that we built for the Old Dominion Copper Company has a fall of only 100 feet in a total length of 1,250 feet, and this line runs by gravity on a daily output of 150 tons.

6th.—*The most important advantage is the low cost of operation and maintenance.* This is due not only to the substantial manner in which these lines are constructed, the less wear and tear, and less power required, but also to the fact that the greater amount of material handled requires no extra labor.

A brief description of some of the "Bleichert" tramways built by us, illustrations of which appear in these pages, will be of interest as demonstrating the practical economy and efficiency of the system.

Its adaptability to mountainous sections is well represented in a number of lines, among which that of the Bunker Hill and Sullivan Mining Co. Idaho, is especially interesting from the fact that it passes over the town of Wardner in a clear span of 1,173 feet, as shown in the accompanying views, and is a good illustration of the positive advantage of long spans in maintaining approximately direct grade lines. The original line had a station at Wardner which practically divided the tramway in two sections. This station was taken out and with it two of the supports, owing to the difficulty experienced in transferring the cars, on account of the steep angles of the converging cables. The long span not only overcame this trouble but also saved the expense of attendance required at this station. The total length of the line is 9,000 feet, and the fall 713 feet, which is amply sufficient for it to run by gravity. At two points where the tramway passes over mountain crests it is supported by rail stations, such as described on page 11. These are low structures and are there-

Wire Rope Tramway (BLEICHERT SYSTEM), built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Split Rock Cable Road Company, of Syracuse, New York, Length of line, 3⅛ miles; daily capacity, 750 tons. View of line above railroad.

fore roofed in to protect them from snow. The tramway is used to transport silver and lead-bearing ores from the mines to the concentrating works at Kellogg, and has carried as much as 50 tons per hour, which is somewhat remarkable, in view of the fact that the buckets only hold from 700 to 750 lbs. each, making the corresponding intervals between them 25 to 27 seconds. The line was only designed to carry 40 tons per hour. The average output is 15,000 tons of ore per month, which is transported at a cost of less than 5 cents per ton per mile, two-thirds of which represents labor and the balance supplies and repairs.

Another interesting line is one recently built for the Silver Lake Mining Co., Colorado. The line is used for the transportation of gold and silver-bearing concentrates from the mine to a point connected with the railroad, a distance of about 8,400 feet. The capacity of the line is about 5 tons per hour, the elevation of the mine above the mill being about 2,100 feet and the descending loads developing about 8 horse-power. Starting out from the loading terminal, the line ascends a mountain slope for a short distance on an inclination of about 1:2½, and rounding the crest of the mountain it pitches down at the opposite side on an inclination of about 1:1.8, crossing snow slides in long spans, one of which is 2,200 feet, or nearly half a mile in the clear, and is the longest span of any similar tramway in the world. There are but 19 supports in the entire distance, making the average spacing outside of the long span referred to over 300 feet. The patent locked-wire rope—⅞ diam.—is used for carrying cables on both sides over the entire length of the tramway. This line works so satisfactorily that another has been built in the same locality for the Iowa Gold Mining and Milling Co., which will have an equally long span in it.

Practical experience has demonstrated that there is no objection to long spans, provided there is nothing to interfere with the proper deflection of the cables. A very good illustration of this is afforded in the tramway of the Susquehanna Water Power and Paper Co., at Conowingo, Md., which crosses the Susquehanna river in two spans of 1,700 feet each, the central support being 100 feet high, and located on an island. The patent locked-wire rope is also used on this line for carrying cables. The line has been in operation about three years.

A span of 1,400 feet occurs in a line of the United Concentration

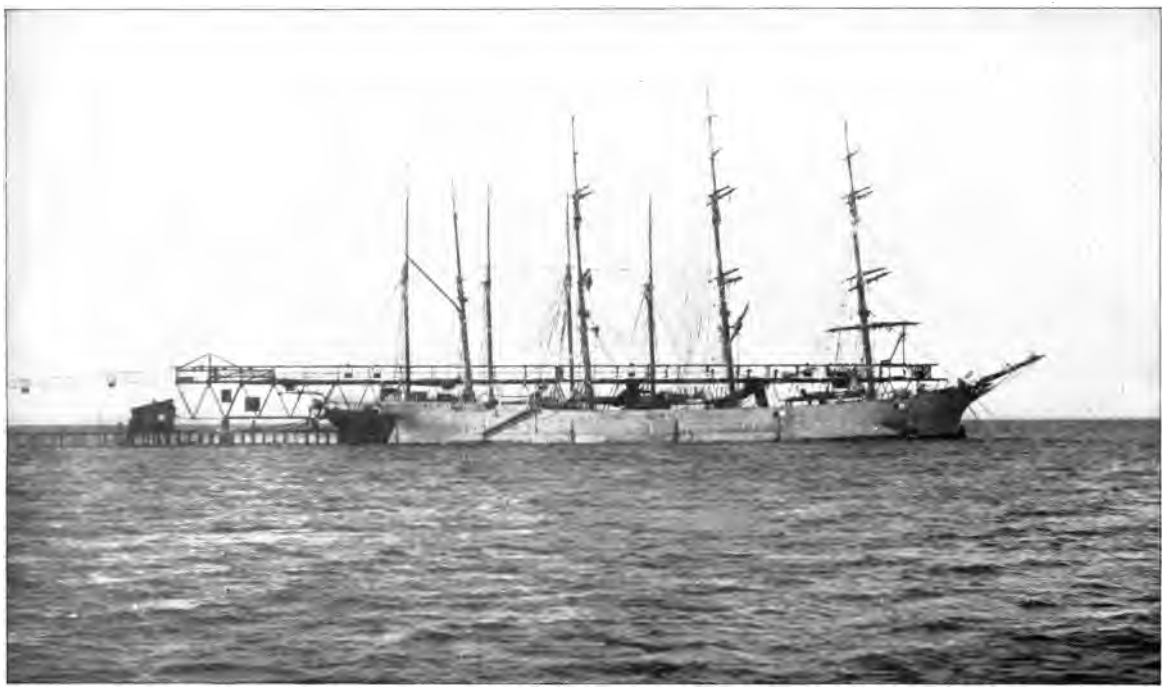
Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Trinidad Asphalt Company, La Brea, Trinidad. Length of line, 5,100 feet ; daily capacity, 750 tons.

Co., of Monte Cristo, Washington, where it crosses a deep ravine, between the loading terminal at the Pride of the Mountain tunnel, and an anchorage-tension station on the crest of a ridge known as Mystery Hill, a distance of 2,000 feet. From Mystery Hill the line pitches at a very steep angle, crossing a snow slide in a span of 1,280 feet. The total fall is 1,820 feet, nearly all of which occurs between Mystery Hill and the works at Monte Cristo, a distance of 4,600 feet. Between the Pride of the Mountain tunnel and Mystery Hill the patent locked-wire rope is used, and the regular interlocked carrying cables on the balance of the line. A separate line, 3,700 feet long, transports the ore from some tunnels in Mystery Hill and terminates in the common discharge terminal at the works.

A span of 1,400 feet also occurs in the Smuggler-Union Mining Company's tramway, at Telluride, Col., where it crosses a deep gulch. The upper support is 350 feet above the lower, and the greatest elevation of the cables above ground about 400 feet. Another line at Guanacevi, Mexico, for conveying ore from Wilson's Mines, contains a span of 1,350 feet. The Penn Glass Sand Co.'s line at Scrubgrass, Venango Co., Pennsylvania, crosses the Allegheny River in a span of 1,100 feet, the patent locked-wire rope being used on the loaded side.

The application of the Bleichert system to the conveyance of coal is well illustrated in the accompanying views of the Royal Coal and Coke Co.'s line at Prince, West Va. The mines are located on a steep mountain slope on the south side of New River, and the tramway conveys the coal to the C. & O. Railroad on the opposite side. The total length of the tramway is 2,800 feet and the fall 820 feet, developing about 50 horse-power on a maximum output of 80 tons per hour. The inclination at the loading terminal is very steep. One of the views shows the structure of this station looking down the line; the other is a view from the north side of the river looking up the line and showing the 665-foot river span. The mine inspector for this district, Mr. H. A. Robson, in his last report, says: "The tramway has proved a great success; but few stoppages have occurred, and no loss of life by this departure from the usual mode of handling coal."

As an instance of the adaptability of the system to comparatively level ground, where the conditions preclude the use of surface tracks, we refer to the line of the Trinidad Asphalt Co., on the Island of Trin-



Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Trinidad Asphalt Company, La Brea, Trinidad. Showing Discharge Terminal on Iron Pier.

idad, for conveying asphalt from the pitch lake to vessels at sea. The length is 5,100 feet and the entire structure is of iron, including the framework of the terminal stations as well as the intermediate supports. The loading terminal is located at a point upon the edge of the lake, and the discharge terminal is an iron pier, 350 feet long, built out in deep water, 1,750 feet from the shore. A view of this end of the line is shown. The fall from lake to pier is but 80 feet, most of which occurs in the last 500 feet, and there are no intervening hills. Seventy-five tons per hour is the capacity of the line, requiring about 20 horse-power. At the loading terminal the line connects with a surface tramway, running in a circuit over the lake, the consistency of the material being such as to render this practicable. While the material is quite soft in the center of the lake, it is hard enough for a considerable distance from the border to support heavy weights ; so hard, in fact, that the original design contemplated an extension of the Bleichert tramway over this lake, with loading terminal near the center and lateral branches to the diggings. It was discovered, however, that the whole mass was in slow motion, the movement only being discernible after the lapse of long intervals by the relative changes in the positions of the small islands and other objects. This led to the adoption of a surface tramway for the lake haul, the termination of the Bleichert line at the border of the lake, and the transferring of the buckets from one line to the other. The surface cars each hold two buckets, and are propelled by an endless rope running continuously in one direction, to which they are attached by means of grips. The same engine that operates the Bleichert tramway also drives the surface line. In order to avoid the slow submergence of the track, which would occur if it had been laid directly on the asphalt surface, the rails are laid on a corduroy of palm, resting on a mattress of cocorite palm leaves, as shown in the view on page 130. At certain points in the circuit, guy lines extend to anchorages on the shore, in order to keep the track in place.

The line of the Split Rock Cable Road Co , near Syracuse, New York, used for the transportation of lime rock, is $3\frac{1}{8}$ miles long and has a daily capacity of 750 tons. It passes over ordinary rolling ground, much of which is farm land, and the contour presents no unusual conditions. This line has been running day and night for nearly seven years, and the cost of operating, as determined from actual records, is

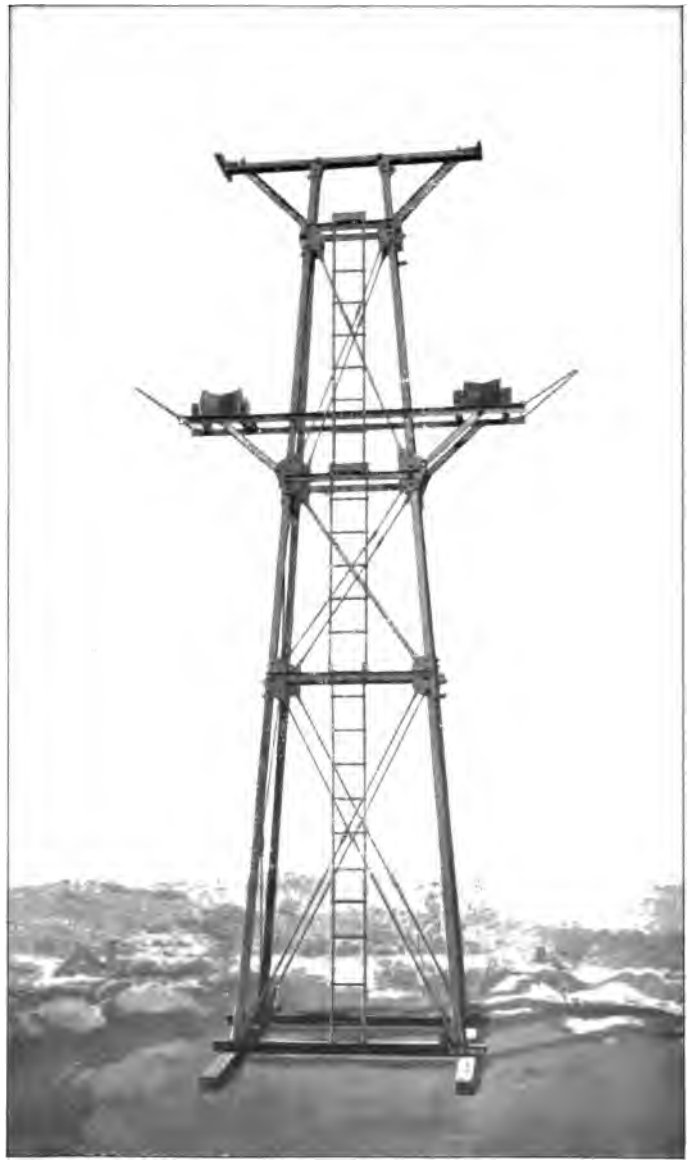
Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the East Shore Terminal Company, Charleston, South Carolina. Length of line, 700 feet; daily capacity, 500 tons. View of Discharge Terminal.

Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Old Dominion Copper Company, Globe, Arizona. Length of line, 1,250 feet; daily capacity, 175 tons.

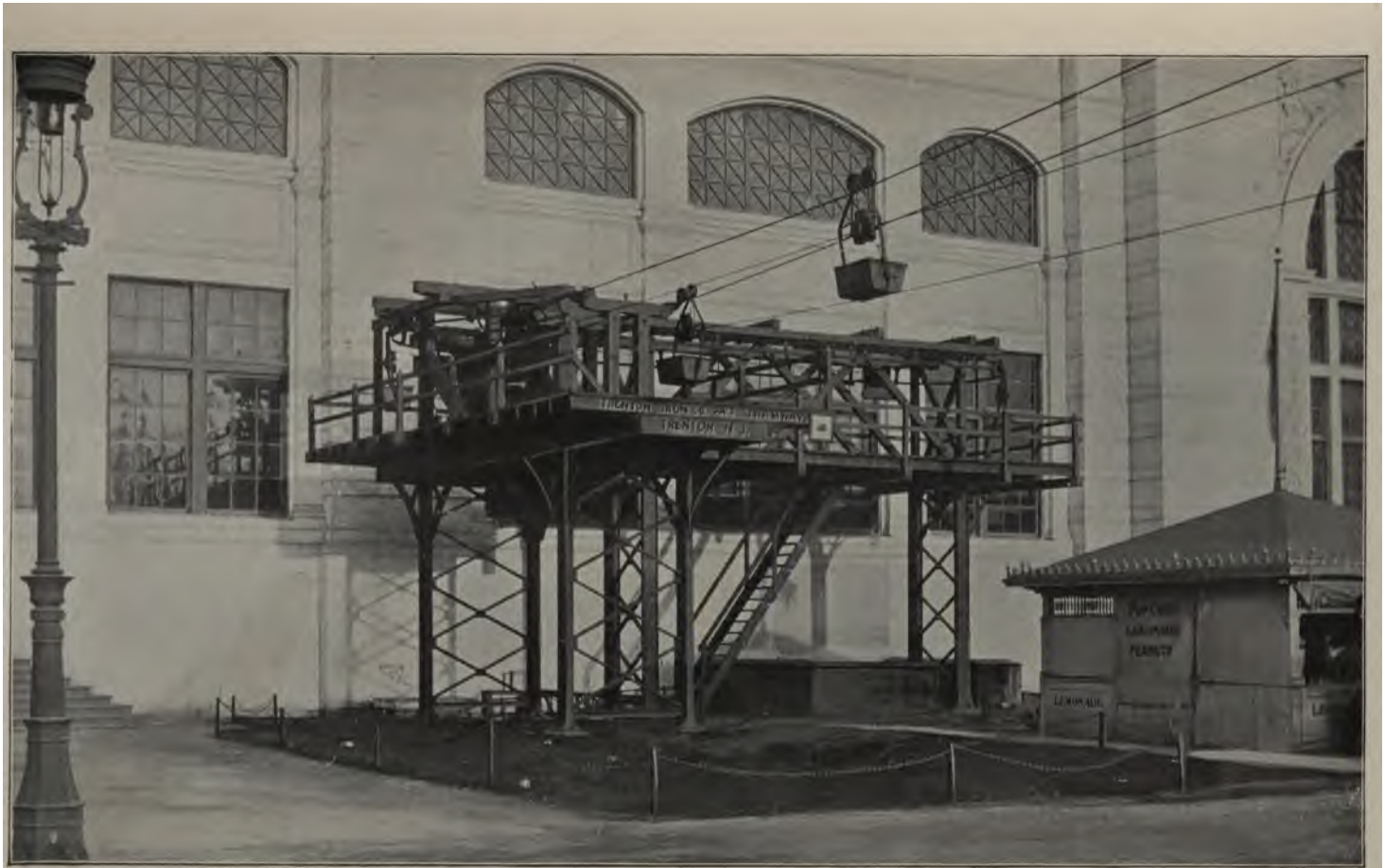
about 6 cents per ton per mile, which includes, in addition to labor and repairs, the expenses of right of way and taxes. The line has proved so satisfactory that the company are building an extension and branch lines, the total length of which will equal if not exceed that of the original line.

We are building for the Compagnie Haitienne, of New York, a line on the Island of Hayti, for the transportation of logwood, the total length of which, when completed, will be 15 miles. The tramway is divided in three sections, each of which constitutes a distinct line in itself, with independent power, the driving stations being located at points where bends occur. The cars at these stations will be transferred in the usual way from one section to the next, by means of shunt rails, so that there will be no rehandling of material. At the driving stations sufficient power is provided not only to run the tramway but also to operate pumps for purposes of irrigation. The entire structure will be of iron.

Visitors to the World's Columbian Exposition at Chicago will recognize in the accompanying view the discharge terminal of an interesting little line which was an exhibit of the Bleichert system, and used at times to carry materials to the Mines building; for this exhibit the Trenton Iron Company received an award. The line crossed the Intramural railway to a loading station near the exhibit of the Pennsylvania Railroad Company, and was one of the features of special attraction.



Iron Support used on Wire Rope Tramway (BLEICHERT SYSTEM) built by THE TRENTON IRON COMPANY. Trenton, New Jersey, for the Compagnie Haitienne, Port de Paix, Hayti. Length of line, 12 miles; daily capacity, 100 tons.



ire Rope Tramway (BLEICHERT SYSTEM) exhibited by THE TRENTON IRON COMPANY at the World's Fair, Chicago, 1893. View of Discharge Termina

Testimonials.

From THE TRINIDAD ASPHALT CO.

NEW YORK, March 9th, 1896.

THE TRENTON IRON CO., TRENTON, N. J.:

Gentlemen—Replying to your inquiry of the 5th inst. we have to state that the plant for the loading of crude asphalt from the pitch lake in Trinidad has been in operation for the past eighteen (18) months and has given very satisfactory results. The asphalt is loaded in buckets at the pitch lake, and, by means of the Bleichert tramway erected by you, is transported to and deposited in the holds of vessels lying alongside the pier with only one handling. We are now transporting from 550 to 650 tons per day when running, and are putting the material on board vessel at a much less cost than under the old system, when the loading was done by means of carts and lighters. We have no hesitation in expressing our pleasure at the very satisfactory results which have been obtained.

Very truly yours,

A. L. BARBER, *President.*

From THE BUNKER HILL AND SULLIVAN MINING AND CONCENTRATING CO.

KELLOGG, IDAHO, March 15, 1896.

THE TRENTON IRON CO., TRENTON, N. J.:

Gentlemen—In reply to your favor of the 5th inst. regarding the operation of our Bleichert tramway, I am pleased to say that the line is working to our entire satisfaction.

The tramway to date has transported from our mine to our mill 450,000 tons of ore. On the larger portion of the line the original carrying cables are still in use, and are apparently good for considerable additional tonnage. The present traction rope has been in use in

transporting 180,000 tons of ore, and apparently is still in good condition. During the last six months (September, 1895, to February, 1896, inclusive) the tramway has transported from mine to mill 236,806 buckets of ore in a total working time of 2,208 hours, of which 172 hours were lost, as follows:

28 hours changing lugs.

93 hours because of repairs (includes coupling in three new pieces of carrying cable at different times).

27 hours on account of accidents.

24 hours on account of telephone line and electric lights being out of order and ore frozen in chutes, and other like causes.

In this period the tramway averaged $107\frac{25}{100}$ buckets of ore per hour of total time, or $116\frac{31}{100}$ buckets of ore per hour of actual time in operation. For the above period the average weight of ore carried by a bucket was 732 pounds. There are 127 buckets (5 cu. ft. capacity) on the line placed 140 feet apart. The tramway carries from the mill to the mine 10 to 12 cords of wood per day, and could carry more if we required it. The operation of the line develops some power which is used for hoisting purposes.

The total operating and repair crew is as follows:

1 foreman.
2 tramway men at mill.
1 brakeman at mine.
1 bucketman at mine.
4 tramwaymen at mine.

I hope the foregoing, together with the data you already have, will give you all the information you wish regarding our tramway,

Yours truly,

F. W. BRADLEY.

From THE VERMONT MARBLE CO.

PROCTOR, VT., April 2, 1896.

THE TRENTON IRON COMPANY, TRENTON, N. J.:

Gentlemen—We have used constantly the wire rope tramway which you installed here in June, 1894, and found it in every way very satisfactory. It conveys sand from a bank to our mill, a distance of about a

Testimonials.

From THE TRINIDAD ASPHALT CO.

NEW YORK, March 9th, 1896.

THE TRENTON IRON CO., TRENTON, N. J.:

Gentlemen—Replying to your inquiry of the 5th inst. we have to state that the plant for the loading of crude asphalt from the pitch lake in Trinidad has been in operation for the past eighteen (18) months and has given very satisfactory results. The asphalt is loaded in buckets at the pitch lake, and, by means of the Bleichert tramway erected by you, is transported to and deposited in the holds of vessels lying alongside the pier with only one handling. We are now transporting from 550 to 650 tons per day when running, and are putting the material on board vessel at a much less cost than under the old system, when the loading was done by means of carts and lighters. We have no hesitation in expressing our pleasure at the very satisfactory results which have been obtained.

Very truly yours,

A. L. BARBER, *President.*

From THE BUNKER HILL AND SULLIVAN MINING AND CONCENTRATING CO.

KELLOGG, IDAHO, March 15, 1896.

THE TRENTON IRON CO., TRENTON, N. J.:

Gentlemen—In reply to your favor of the 5th inst. regarding the operation of our Bleichert tramway, I am pleased to say that the line is working to our entire satisfaction.

The tramway to date has transported from our mine to our mill 450,000 tons of ore. On the larger portion of the line the original carrying cables are still in use, and are apparently good for considerable additional tonnage. The present traction rope has been in use in

1,700 feet, each crossing the Susquehanna River at this point. We are perfectly satisfied with the operation of this tramway, as it gives us scarcely any trouble, and the costs for repairs up to this time are almost too small to note. We will be glad to show this tramway to any one you may wish to send here, and if you wish you can refer parties to us.

Yours truly,

J. SMITH, *Treas.*
Susquehanna Water Power & Paper Co.

[COPY.]

From THE OLD DOMINION COPPER CO.

GLOBE, ARIZONA, April 24th, 1892.

THE TRENTON IRON COMPANY, TRENTON, N. J.:

Gentlemen—I have your favor of the 13th inst., and note contents of same carefully.

The Bleichert tramway procured from you last year was erected by us last fall, and put in operation on the 6th of January, 1892. Since that time it has been running daily.

The line is 1,224 feet long and is used to convey copper ore and limestone from the rock-house at our mines to the smelting plant, the grade being sufficient to run the line automatically but not to develop any additional power. Over this tramway we are now conveying daily 110 tons of copper ore and 30 to 40 tons of limestone in nine hours, working time, at a cost of 8.9 cents per ton. We could easily increase the capacity greatly, as we have frequently run at the rate of 25 tons an hour, which would of course bring the cost down proportionately.

We had no trouble in the erection of the line, and have none in working it. Everything about it works so smoothly that no extra attention is needed and no trouble caused, as we are sure of the ore-supply in any kind of weather. I am more than pleased with the working of this tramway, and can earnestly recommend it to those requiring a cheap and reliable method of transporting ore from one point to another.

Yours truly,

(Signed) A. L. WALKER, *Sup't.*
The Old Dominion Copper Co.

LIST OF BLEICHERT TRAMWAYS BUILT BY THE TRENTON IRON CO., TRENTON, N. J., U. S. A.

FOR WHOM.	LOCALITY.	Material transported.	Capacity in tons per day of 10 hours.	Length of line, in feet.	Difference in level between terminals, in feet.	Horse-power required.	Horse-power developed.	REMARKS.
E. Soler	Baracoa, Cuba, W.I.	Bananas	300	12,475	600 fall.	....	8	The whole of the descent is in the first three-quarters of a mile of the line. The loads going down this incline operate the balance of the line.
Edgewater Lime Works	Edgewater, N. J.	Lime	100	360	20 rise.	4	....	
Pottsville Iron and Steel Co.	Pottsville, Pa.	Cinder	50	1,100	70 "	10	....	Intermediate loading station at mill, at which cars are taken off and put on at will.
Solvay Process Co.	Syracuse, N. Y.	Lime rock	750	16,500	239 fall.	12	....	
Bi-Metallic Mining Co.	Granite, Mont.	Silver ore	200	9,750	1,225 "	....	15	Power developed utilized to carry back 50 tons per day, and also to run crushers and crush all the ore shipped.
Granite Mountain Mining Co.	" "	" "	200	8,750	1,297 "	....	20	100 tons of back freight carried. For over 2,000 feet in length of this line the grades are over 1 in 2.
Nowell Gold Mining Co.	Juneau, Alaska.	Gold ore	200	11,600	2,135 "	....	45	Two long spans, one of 1,700 feet, and one of 1,200 feet.
Witherbees, Sherman & Co.	Port Henry, N. Y.	Iron ore	500	3,668	406 "	....	14	
Laurentide Pulp Co.	Montreal, Can.	Wood pulp	100	1,500	15 rise.	4	....	This line raises pulp 100 feet from lower mill floor and carries it across the Grand Mère Falls of the St. Maurice River.
Compromise Mining Co.	Aspen, Colo.	Silver ore	250	3,200	920 fall.	....	20	Power developed used to operate an elevator at each terminal and an intermediate station.
Aspen Public Tramway Co.	" "	" "	250	9,850	2,409 "	....	60	
Keeler, Holcombe & Co.	Kelly Switch, N. M.	" "	75	7,500	1,850 "	....	12	
Oregon Gold Mining Co.	Cornucopia, Oreg.	Gold ore	100	5,000	2,000 "	....	14	
Warner's Portland Cement Co.	Syracuse, N. Y.	Clay	300	1,056	48 rise.	4	....	
Silver Age Mining and Milling Co.	Idaho Springs, Colo.	Silver ore	100	6,240	989 fall.	....	6	
Pillsbury-Washburn Flour Mills Co.	Minneapolis, Minn.	Wheat	435	320	Level.	4	....	
Mountain Ledge Gold Mining Co.	Sierra City, Cal.	Gold ore	125	5,800	1,600 "	....	16	
Bunker Hill & Sullivan M. & C. Co.	Wardner, Idaho	Silver ore	400	9,000	713 "	....	16	—50 tons of back freight carried per day.
" " " "	" "	" "	200	1,200	370 "	....	4	
East Shore Terminal Co.	Charleston, S. C.	Cotton	500	650	Level.	5	....	Supports all carried on roof trusses of buildings. Automatic dumping platform cars are used. Double-cage elevator at loading terminal.
" " " "	" "	"	500	700	"	5	....	
Royal Coal and Coke Co.	Prince, W. Va.	Coal	800	2,800	820 fall.	....	50	—Last span 665 feet in the clear; crosses New River.
Magnetic Iron Ore Co.	Benson Mines, N.Y.	Iron ore	800	250	25 rise.	10	....	Buckets are fitted with wheels, and are detached from line at loading terminal.

LIST OF BLEICHERT TRAMWAYS BUILT BY THE TRENTON IRON CO., TRENTON, N. J., U. S. A.

FOR WHOM.	LOCALITY.	Material transported.	Capacity in tons per day of 10 hours.	Length of line, in feet.	Difference in level between terminals, in feet.	Horse-power required.	Horse-power developed.	REMARKS.
Macate Gold Mining Co.	Peru, S. America.	Gold ore.	100	10,450	4,920 fall.	....	16	This line located in the Andes, and constructed for mule-back transportation, no piece weighing over 300 pounds. 1,000 gallons of water carried up to mine per day.
Barber Asphalt Paving Co.	Buffalo, N. Y.	Stone	700	450	50 rise.	7	....	
Old Dominion Copper Co.	Globe, Ariz.	Copper ore.	175	1,250	100 fall.	....	34	
Holy Moses Mining Co.	Creede, Colo.	Silver ore.	250	2,000	1,020 "	....	21	—The fall at upper end of line is 60 feet in 100.
Va. and Pittsburg Coal & Coke Co.	Fairmont, W. Va.	Coal.	800	600	20 "	5	....	
Wilson's Mines.	Guanacevi, Mexico.	Silver ore.	100	6,000	440 "	....	....	—One clear span of 1,350 feet.
Amethyst Mining Co.	Creede, Colo.	" "	125	8,250	1,186 "	....	12	
Smuggler-Union Mining Co.	Telluride, Colo.	" "	100	5,150	1,800 "	....	24	
La Gran Fundicion Nat. Mexicana	Santa Catarina, Mex	" "	100	8,650	1,515 "	....	9	
San Miguel Con. Gold Mining Co.	Telluride, Colo.	" "	250	3,000	845 "	....	17	
Hawkeye Gold Mining Co.	Deadwood, So. Dak	Gold ore.	150	4,000	475 "	....	4	
Penn. Glass Sand Co.	Emlenton, Pa.	Sand	250	5,360	345 "	....	2	Lower end crosses the Allegheny River in a span of 1,100 feet.
Susqueh'a Water Pow'r & PaperCo.	Conowingo, Md.	Wood, Coal and Paper Stock	750	3,500	Level.	3	....	Crosses the Susquehanna River in two spans, each of 1,700 feet, the central tower, 100 feet high, being located on an island.
United Concentration Co.	Monte Cristo, Wash.	Gold ore.	100	6,600	1,820 fall.	....	16	Span of 1,400 feet across a ravine, and one of 1,300 feet over a snow slide.
" " "	" " "	" "	100	3,700	1,110 "	....	8	—Crosses snow slides.
Trinidad Asphalt Co.	La Brea, Is. of Trin.	Asphalt.	750	5,100	80 "	20	....	Loading terminal connects with a surface line over pitch lake, and discharge terminal is located on a pier at sea.
Vermont Marble Co.	Proctor, Vt.	Sand.	150	1,600	140 rise.	7	....	
Smuggler-Union Mining Co.	Telluride, Colo.	Silver ore.	100	5,500	1,200 fall.	....	8	—Contains a span of 1,400 feet.
Silver Lake Mining Co.	Silverton, Colo.	" "	50	8,640	2,100 "	....	10	—Contains a span of 2,200 feet.
Joaquin Maiz.	Monterey, Mexico	" "	200	7,260	1,888 "	....	30	
Compagnie Haitienne.	Port de Paix, Hayti.	Logwood.	100	61,700	330 "	60	....	—Line is in three sections.
Bachelor-Commodore Mining Co.	Creede, Colo.	Silver ore.	200	3,120	1,000 "	....	6	Ore from upper mine is delivered to bins at a lower loading station, by a gravity incline with special self-dumping buckets.
Iowa Gold Mining & Milling Co.	Silverton, Colo.	" "	75	9,300	2,320 "	....	17	—Contains a span of 2,200 feet.
United Globe Mines.	Globe, Arizona.	" "	200	2,800	360 "	....	3	

Wire Rope Tramway (ACME SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Cedar Hill Lime Company, of Port Kennedy, Pennsylvania. Length of line, 1,450 feet ; daily capacity, 150 tons.

The Acme System

OF

Wire Rope Tramways.

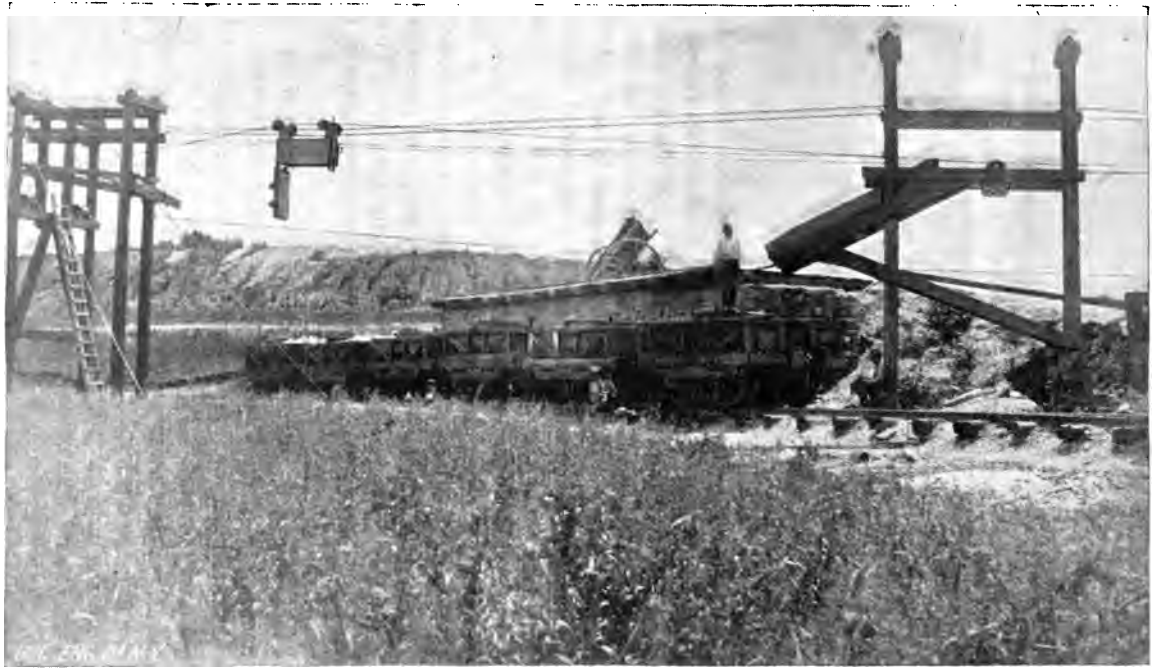
A. H. DeCamp Patents.

In this system the functions of supporting and propelling the loads are performed by independent members, as in the Bleichert system, but it differs essentially from the latter system in the fact that the cars are adapted to run on surface rails as well as overhead cables, without detaching from the traction rope. The patent interlocked cable, as described on page, 9 is recommended for the suspended trackway, although cases may occur where it is desirable to use the "locked-wire" rope, which is stronger and requires no couplings.

The trackway is double; that is, the cars are suspended on either side, from two parallel cables, and the traction rope travels centrally in respect to them, the cars being attached to it by means of patent grips. The double trackway permits of very heavy individual loads, as each line supports but half the weight, and consequently it is adapted to a heavier output than any other system.

The principles which govern the height and spacing of the supports are the same as in the Bleichert system. The supports may be of rough or sawed timber or iron, as preferred, and are simple in construction and easily erected. The double trackway brings the cables nearer the posts, which possesses the advantage of greater rigidity.

The cars are detached automatically at the terminal stations, and conducted to the ground on to surface tracks, and the terminal structures therefore are very simple affairs, since no overhead rails have to be provided for. For quarry work this is very convenient; light, portable tracks being used, which can be shifted as the face of the quarry is worked off.



Wire Rope Tramway (ACME SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Cedar Hill Lime Company, of Port Kennedy, Pennsylvania. Length of line, 1,450 feet; daily capacity, 150 tons. Showing how cars are automatically loaded.

The cars may be arranged to dump either from the side or bottom, as circumstances may require, or ordinary buckets may be used which discharge by tilting. The bottom dump cars are preferred, as they permit of an automatic discharge at any desired points, a feature well illustrated in the views on pages 34 and 36 of the Cedar Hill Lime Company's line at Port Kennedy, Pa., one showing how railroad cars midway between the terminals are loaded, without arresting the motion of the tramway car, and the other how the stone is similarly deposited at any of the kilns where needed.

The use of cars adapted to traverse surface rails as well as suspended cables makes the introduction of side lines as feeders to the main tramway a simple matter. For the same reason the construction of automatic curves is much simplified. In passing high ridges, where the downward pressure in the moving rope often requires expensive rail stations or other special supporting structures, in other tramways, the great advantage of being able to come down to surface tracks at such points can be fully appreciated.

By attaching the rope to the bottom of the cars no overhead construction of any sort is required at the terminal stations, as all the driving mechanism, sheaves, etc., may be placed below the floor or surface level, leaving everything above entirely clear for the passage of the cars. On account of the great stability of the cars the speed may be as great as, if not greater than, in any other system.

Where the ground for the greater part of the distance admits of surface tracks, but is rugged in places, with ravines and rivers to be crossed, a combination of surface tracks and "Acme" tramway may be employed to advantage, the latter being applied only to the bridging of the valleys, streams, and other points where it would be impracticable to lay surface tracks. By transporting the material thus in a continuous string of comparatively light loads (each car being provided with an independent grip), it is evident that a very large tonnage can be sent daily over a surface road of light rails, while the suspended way renders bridges and trestlework unnecessary, and the first cost of the roadway is therefore considerably reduced.

We commend the Acme system to quarrymen and miners who have large outputs to transport.

Wire Rope Tramway (ACME SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Cedar Hill Lime Company, Port Kennedy, Pennsylvania. Length of line, 1,450 feet ; daily capacity, 150 tons. Showing how stone is deposited at kilns.

The cost of operation, maintenance, and repairs in this system will compare favorably with that of any other mode of transportation.

We present a view of a line at Ivanhoe, Va, used by the Pennsylvania Zinc and Iron Co, for transporting iron ore from a branch of the Norfolk & Western Railroad to their works on the opposite side of New River, the tramway being in one span of 580 feet. The capacity is 250 tons per day.

From the CEDAR HILL LIME WORKS, PORT KENNEDY, PA.

PORT KENNEDY, PA., August 10th, 1893.

THE TRENTON IRON COMPANY, TRENTON, N. J.:

Gentlemen—Respecting the operations of our Acme steel tramway, bought of you, we are pleased to say that our experience with it, covering now something over a year, has been highly satisfactory. We investigated all systems and methods that might be applied to our work before ordering this tramway, and while advised by you that since it was an entirely new thing, it must naturally be somewhat experimental, its entirely successful operation from the day of starting has settled our opinion that we selected the most reliable and economical machine for our work. The cars are taken directly to the rock to be loaded in the quarry, which is a great convenience and saves much handling. The automatic discharge of the stone, either into the railroad cars, just beyond the quarry, or at any of the kilns, is one point of the operation which we greatly appreciate. In short, the tramway is a success—it has saved us time, patience and money—just what we bought it for. You may use our name freely as reference.

Yours very truly,

A. BLAIR & CO.

Wire Rope Tramway (ACME SYSTEM) built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Pennsylvania Zinc and Iron Company, Ivanhoe, Virginia. Length of line, 580 feet ; daily capacity, 250 tons.

The Roe System

OF

Wire Rope Tramways.

ROE & BEDLINGTON & ROE'S PATENTS.

The Roe patent single-rope system possesses the merit of simplicity, and is offered to meet the demand for a more economical installation than the Bleichert or Acme. As implied in the title, but one rope is employed, which performs the dual function of supporting and propelling the loads. The rope is endless and travels continuously about terminal sheaves in a parallel circuit, the two members of which or lines, of course, move in contrary directions, the loaded buckets being carried by one of these and the empties returned by the other, or if desired loads may be carried each way.

In the original "Hodgson" single-rope system, the first to be introduced in this country, the buckets were hung from saddles or box-heads, as they are more commonly known, which straddle the rope, These consisted of light malleable iron boxes, containing what are termed "bearing blocks," which are pieces of rubber or wood that bear against the rope. The frictional contact between these blocks and the rope was depended on solely to keep the box-heads in place, and consequently the system was barred to lines where grades occur steeper than 1:4. On steeper inclinations there is danger of the box-heads slipping. In the Hallidie single-rope system this difficulty is overcome by suspending the buckets from steel clips of peculiar construction, which are permanently fastened to the rope. This, however, necessitates the loading and unloading of the buckets while they are in motion, which is a great objection to this system, as these lines in consequence can only be run at a very moderate speed—that is, about 180 feet per minute—which requires a large outfit of buckets. To obviate the objectionable feature of loading on the fly, an automatic loader has

ROE PATENT BOX-HEADS.

been devised, consisting of a hopper that travels with the buckets in the act of loading, and returns to its original position at the bin after each bucket is loaded, but it is little better than a makeshift. Another objection to the Hallidie system arises from the fact that it only permits of a half lap of the rope about the terminal sheaves, so that where considerable power is required or developed expensive grip wheels must be used.

The Roe system not only overcomes all the objectionable features of the Huson and Hallidie, but improvements have been introduced in the general design of the supports and terminal machinery which make it possible to carry much heavier individual loads, and consequently render the system adapted to correspondingly greater outputs.

In the adoption of box-heads for supporting the pendant buckets the Hodgson system has been followed more closely, but the ordinary bearing blocks are replaced by iron saddle pieces with small fins or lugs on the under faces, which mesh with the strands of the rope in such a way that slipping is avoided even on very steep grades. These saddle-pieces can be readily replaced as they wear out and constitute the distinctive feature of the Roe system. Referring to the accompanying cuts it will be observed that the box-head is provided with a pair of wheels at one side with grooved rims. The object of these is to free it from the rope at the terminal stations, which operation is performed automatically by providing rails at these stations, or flat bars suspended to the framework, the terminal points of which are bent down or so disposed to the rope as to come under the box-head wheels. The momentum of the buckets transfers the box-heads from the rope to the rail, by means of which the buckets are conveyed to convenient points of loading and discharge, as the case may be, while the motion of the rope continues uninterrupted. In this respect it is similar to the Bleichert system. In attaching the buckets again, the box-heads simply have to be pushed off on to the rope, to which they are self-fastening, and there are no intricate grips to be manipulated or kept in repair.

The method of supporting the rope is also novel. On those standards that, by reason of long spans or sharp ridges, or from any other cause, have much weight to sustain, the pressure is distributed over two or more tandem sheaves. These sheaves are mounted on

Support (ROE SYSTEM) Showing Quadruple Mount.

beams that oscillate with the passing buckets in such a way as to relieve the rope from undue bending strains, so adding greatly to its life.

Even in lines possessing no unusual conditions of contour this arrangement, by enabling long spans to be made, reduces the number of supports to a minimum, thereby effecting considerable saving in the cost of the framework and erection. The sheaves are made with deep flanges to guard against the danger of the rope leaving the tread of the grooves.

Where the difference in the elevation of terminal points exceeds one-seventh of the horizontal distance, the power developed by the descending loads will usually be sufficient to run the line by gravity, in which case its operation is controlled by brakes at one of the terminal stations, and great economy is effected where such conditions prevail.

The advantages of the Roe system may be briefly summed up as follows:

1st.—*It is simple in construction, and therefore cheap;* but one rope of the ordinary lay being used, requiring no couplings or special fittings of any kind

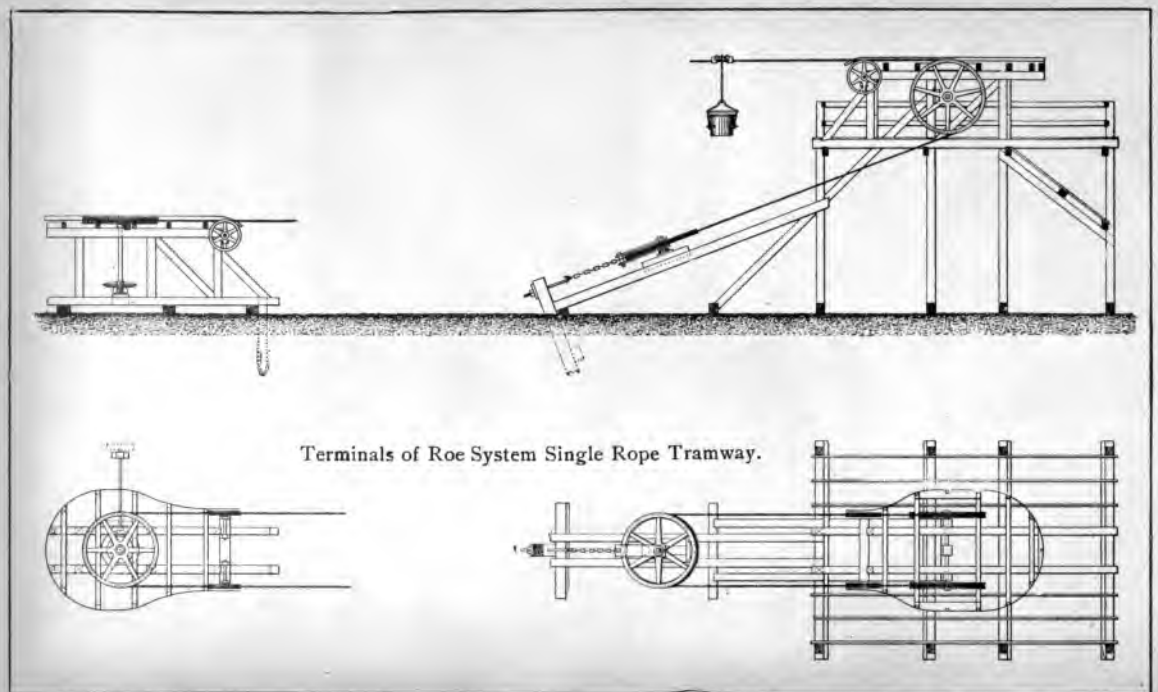
2d—*Steep grades can be surmounted,* since the patent saddle-pieces effectually prevent slipping.

3d—*The box-heads are self-attaching as well as self-detaching* and no skill therefore is required in handling them.

4th—*Few supports are required,* by reason of the employment of tandem sheaves, as described.

5th—*No danger of the rope dropping from the supporting sheaves,* This is a common occurrence in other single-rope lines where the rope rests on a single sheave at either side of each support, and the source of much delay and annoyance.

6th—*A high speed is practicable,* which enables a given output to be transported by fewer buckets than other single-rope lines, which must be run at moderate speeds.

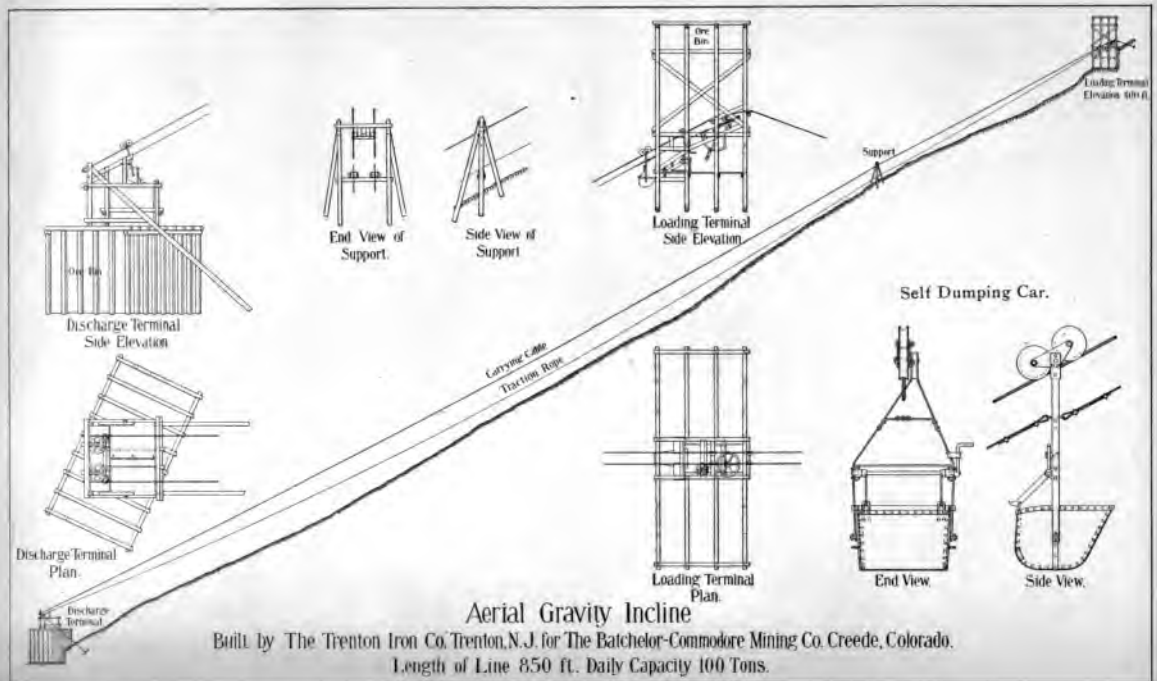


Terminals of Roe System Single Rope Tramway.

Special Types of Wire Rope Tramways.

Cases frequently occur where special forms of wire rope tramways may be used to advantage. For instance, lines are sometimes constructed with fixed cables serving as tracks for the cars, in which the traction rope is given a reciprocating motion, instead of running continuously in one direction, as in the preceding systems. There are usually but two carriers in this case, which are so arranged that as one arrives at either terminal the other arrives simultaneously at the other terminal. This style of conveyor, of course, is limited to comparatively short lines of communication, such, for instance, as the transferring of material across a river or ravine, or from one building to another.

Where the inclination is very steep, aërial inclines are sometimes constructed which operate in the same manner as an ordinary engine or gravity plane, the carrying cables simply performing the function of the surface tracks. If the load is an ascending one, the line is run by power applied at the upper end; but if it is a descending one, gravity becomes the motive power. The accompanying illustration, representing a line of the Bachelor-Commodore Mining Co., Creede, Col., is a good illustration of a self-acting wire rope gravity incline. The total length of the line is 850 feet and difference in elevation of terminal points about 400 feet. The two cars each traverse 1-in. steel cables and are attached to a ½-in. traction rope, operated by brakes at the upper terminal station. Loads of 12 cwt. are carried, and the ore delivered to bins, and thence to a longer wire rope tramway of the Bleichert type, which transports it to the Denver & Rio Grande Railway. One hundred tons of ore per day are transported thus at a very low cost. A similar line is operated by La Gran Fundicion National Mexicana, near Santa Catarina, Mexico.


Ore Bin
Discharge Terminal
Side Elevation
End View of
Support.
Side View of
Support
Ore Bin
Loading Terminal
Side Elevation.
Loading Terminal
Elevation 400 ft.
Support
Self Dumping Car.
Carrying Cable
Traction Rope
Discharge Terminal
Plan.
Loading Terminal
Plan.
End View.
Side View.
Discharge
Terminal
Aerial Gravity Incline
Built by The Trenton Iron Co. Trenton, N.J. for The Batchelor-Commodore Mining Co. Creede, Colorado.
Length of Line 850 ft. Daily Capacity 100 Tons.

There was a remarkable line of this character at Aalsund, Norway, which had one clear span of 2,200 feet, from loading to discharge station, the general inclination of which was about 45 degrees.

The traction rope is usually endless, passing around sheaves at each terminal. This is especially desirable in cases where the sag otherwise would bring the rope in contact with the ground or interfere with objects under the line. This arrangement also permits of operating from the lower terminal if desired, as exemplified in a line for conveying stores from the town of Gibraltar to the fortifications at the summit of the rock. This line is 2,200 feet long, has a vertical ascent of 1,200 feet, and the two cars each carry loads of 1,000 lbs. The motive power is supplied by an engine at the lower terminal, and the cars are run at a speed of 450 feet per minute. There are six intermediate supports, the last span from a rock bluff to the town being 1,150 feet in the clear.

We also manufacture equipments specially designed for the conveyance of materials from one part of a factory to another, in which the carrying cables are replaced by rigid rails. The desideratum of rolling-mill men for some efficient means of conveying hot billets, slabs and ingots has thus been met. In a line of this character, built for the Wellman Steel Co., of Chester, Pa., the trolleys or carriages travel on deck beams, supported by iron standards, and move continuously by means of an endless traction rope, to which they are permanently attached, and which is driven by a small electric motor, at a speed of about 150 feet per minute. From each carriage depends a platform hanger of peculiar construction for supporting the billets. These hangers are self-dumping. The billets are also loaded automatically at the hot shears, from which point the carriers ascend an incline of 15 feet in 66, which connects with the main line, 220 feet in length, extending to each side at right angles to the incline. A similar line was built for the Pottstown Iron & Steel Co., which was designed to carry slabs and ingots up to 5,000 lbs. in weight.

This method of operating carriers, permanently attached to the traction rope at a moderate speed, has been applied to a light portable rig, specially designed for the conveyance of sugar cane, but instead of rigid track rails in this case wire rope is used.

The cut on the following page illustrates the Lamb Patent Log-

GILL ENG. CO N.Y.

Skidding Wire Rope Tramway, which is adapted to hauls up to half a mile in length. A line of our patent interlocked carrying cable is strung over supporting brackets attached to convenient trees. These brackets are so constructed that they can be quickly taken down and put up in other places as the cutting progresses. The logs are secured by grip blocks, suspended from trolleys running on the carrying cable, and moved by a light endless traction rope driven by a reversible engine, with a single oval-grooved drum, about which the rope is lapped two or three times. In logging a swamp the engine is mounted upon a boat or scow, but when used as a lateral feeder to a logging railroad it is mounted on a car designed especially for the purpose.

By means of a lateral hauling device logs can be drawn in on either side of the main cable a distance of 500 feet, thus making the area that can be cleaned up at "one setting" a half a mile long by 1,000 feet wide. The automatic grip blocks are operated in such a manner that the logs are raised without the exertion of manual power. This system requires a smaller and less expensive engine than other logging systems, and consequently possesses all the advantages of simplicity. The crew consists of an engineer and fireman (who also cuts wood for fuel when not firing), two tongsmen, one loader and one unloader, in all six men.

We manufacture equipments for similar lines adapted to be operated by electric motors, and special wire rope tramways for conveying refuse material from saw-mills.

We also manufacture equipments for Lamb's patent system of canal-boat towage by means of suspended traveling electric motors.

LIST OF TRAMWAYS OF SPECIAL DESIGN BUILT BY TRENTON IRON CO.

NAME.	LOCATION.	MATERIAL TRANSPORTED.	Length—Feet.	Load—Tons.
Thomas Craig	Trenton, N. J.	Earth	500	1½
Wellman Iron & Steel Co	Thurlow, Pa.	Billets	270	½
St. Bernard Coal Co	Earlington, Ky.	Culm	600	½
Pottstown Iron Co	Pottstown, Pa.	Ingots	375	4
Eagle Oil Co	Communipaw, N. J.	Ashes	600	2
Union Iron Works	Buffalo, N. Y.	Iron ore	1,900	1
La Gran Fundicion National Mexicana	Santa Catarina, Mex	Silver ore	850	½
Balbach Smelting & Refining Co	Newark, N. J.	Lead dross	320	¼
Glens Falls Paper Mill Co	Fort Edward, N. Y.	Paper pulp	400	1
Joseph Rigney	Manzanilla, Cuba	Sugar cane	2,640	
Bachelor-Commodore Mining Co	Creede, Col.	Silver ore	850	½

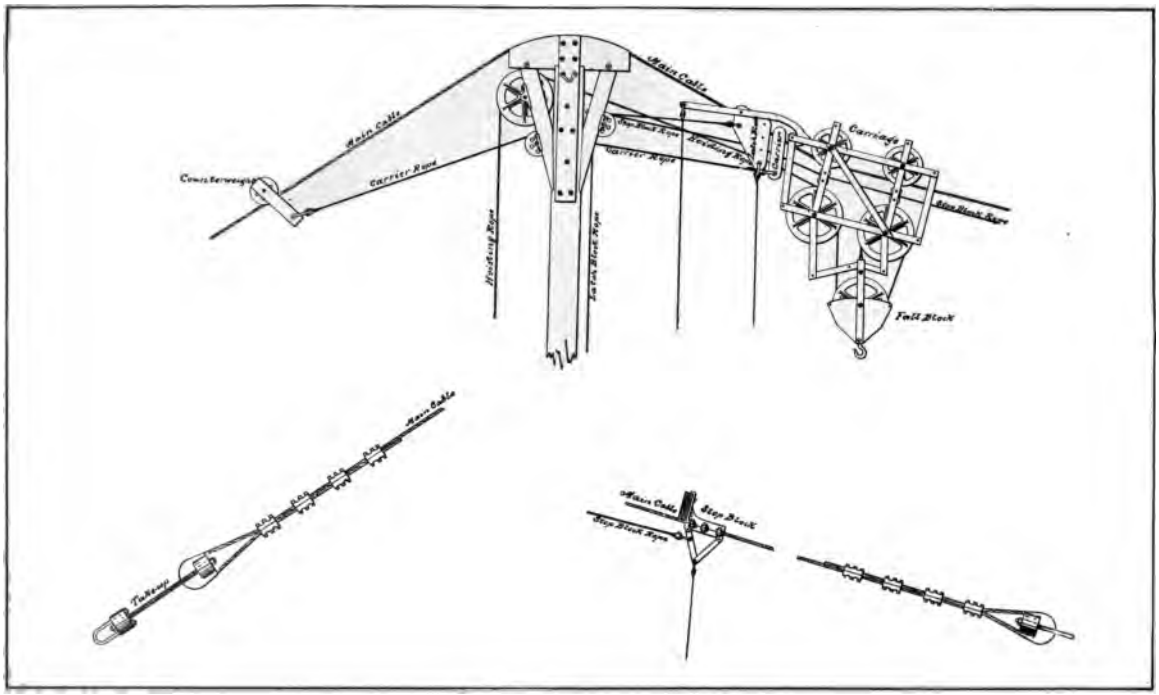
Wire Rope Inclined Hoist-Conveyor, built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for Fred. Kocher & Co., Avondale, New Jersey. Span, 250 feet; load, 3 tons. View shows manner of holding carriage at occasional points of loading.

Cable Conveyors.

Considering the fact that the weight which a cable will sustain safely is ~~inversely~~ proportional to the amount of sag or deflection, it will be readily understood how it is that very heavy loads are handled by means of a wire cable. The greater deflection necessary on such lines, however, precludes the introduction of intervening supports, or at least renders them undesirable, and as a rule, therefore, such cable lines are confined to single spans, the length of which is determined by the distance which the material is to be moved and the height of the supports And used in the construction of the new dam at Holyoke, Mass., has a clear span of 1,615 feet, which is the greatest yet built.

The plants may be either simple conveyors, such as used in transferring materials across rivers or ravines, or they may partake of the nature of hoists also, and in this adaptation is found their widest application for quarry work, canal excavation, stripping. piling. dam building, levee construction, and other purposes, where derricks would be cumbersome or impracticable, on account of the limited area which they cover. The advantage, moreover, of having a clear space for the men to work in is one to commend our conveyors to quarrymen and contractors, to say nothing of their exemption from injury by flood, fire or explosions.

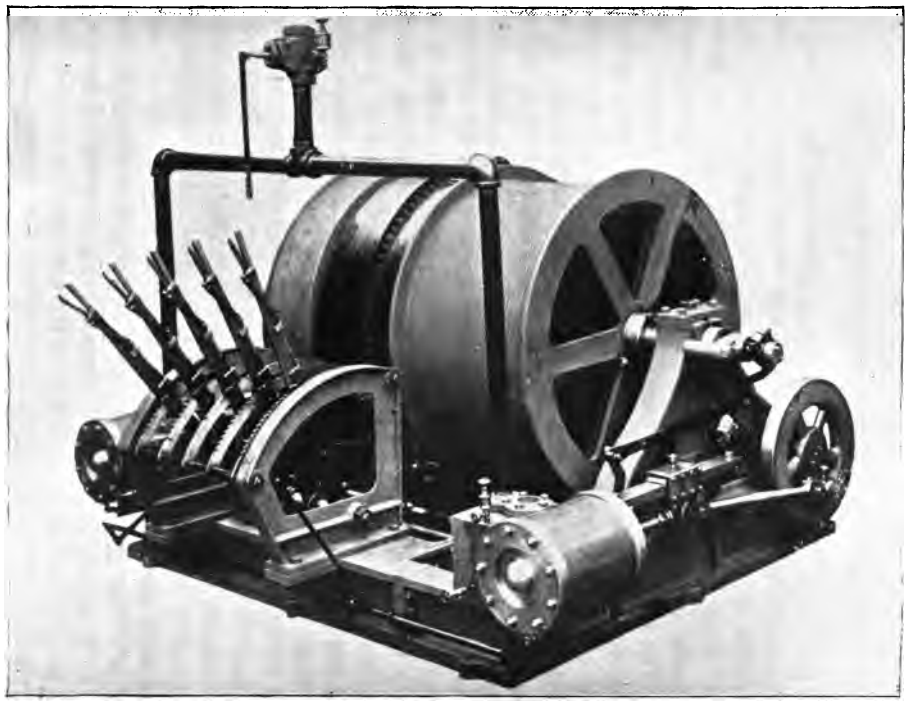
Lines adapted to hoist as well as convey the loads are of two types, one of which, applicable to inclines only, in which the carriage descends by gravity and but one operating or hoisting rope is used, and the other in which the hoisting and conveying are done by separate ropes, and are applicable either to horizontal lines or lines in which the inclination is not sufficient for the carriage to run down by gravity alone. In either case the carrying cable rests upon saddles or grooved blocks of hard wood, forming the peaks of the supports, and is anchored firmly to the ground at each end, a turn-buckle or take-up usually being provided at one of the anchorages for maintaining the proper deflection. The supports are pyramidal towers of wood or iron, as preferred,


Main Cable
Main Cable
Counterweight
Carrier Rope
Hoisting Rope
Latch Block Rope
Stop Block Rope
Carrier Rope
Hoisting Rope
Carrier
Carriage
Stop Block Rope
Fall Block
Main Cable
Tuckup
Main Cable
Stop Block
Stop Block Rope

although in many cases, especially when the loads do not exceed one or two tons in weight, these are simply A frames or masts guyed with wire ropes.

INCLINED CABLE HOIST-CONVEYORS.

Inclined cable hoist conveyors have been used for a long time and quite extensively in the slate quarries of Pennsylvania and Vermont, and also for quarry work in other localities. The hoisting rope is operated from a drum with friction connections, and the common arrangement is to mount these with the engine and boiler on one bed plate. The loading and unloading is effected at definite points. If the loads are to be elevated from a quarry, for instance, a stop or buffer-block is clamped to the carrying cable at the loading point, which arrests the carriage in its descent, and allows the bucket, skip, or whatever appliance may be used for holding the load, to drop to the place of loading. The hoisting rope is reeved through the carriage and fall block with a sufficient number of parts so that the hoisting resistance is less than the resistance to traction. Applying power to the hoisting drum the load rises till the fall block encounters the carriage, when the latter proceeds to move up the line till the point of discharge is reached. Here it engages a latch clamped to the carrying cable, which prevents the carriage from running back while lowering the load. The power is thrown out as soon as the carriage engages this latch, and the lowering of the load effected by means of a brake on the drum. The latch and stop blocks are so designed that they can be shifted to correspond with varying points of loading or discharge. In some cases where the upper point of discharge or loading is fixed the carriage is held by a V-shaped frame, pivoted at the mast or support, and which is dropped over the carriage. The latter is freed by means of a light rope which hangs from the back end of this frame or latch, as the case may be, and descends by gravity, pulling the hoisting rope out with it. The limiting or least inclination on which such a line will work is about one in three. If the load is a descending one the operation is similar, but in this case lighter inclinations are practicable, the limit being a fall of about one in five for ordinary loads. The power required is considerably less, since this is only applied in raising the loads from the ground.



ENDLESS ROPE HOIST-CONVEYOR ENGINE.

As an example of a hoist-conveyor of this character a view is presented of one at Avondale, N. J., which shows the construction of the hoist carriage and fall block; also the latch block for holding the carriage while loading. The support consists merely of a mast guyed with wire rope, making a very simple and inexpensive rig. The carriage in this case is provided with a lever, which being brought to bear against the under side of the main cable serves to hold the carriage at points where loads are occasionally raised. This is simply a makeshift to avoid the trouble of frequently moving the latch block.

If it is desired to load and unload at various points along an inclined hoist-conveyor the carriage may be attached to an independent rope operated in conjunction with the hoisting rope, except when raising or lowering the load, when it is held by a brake on the drum from which it is driven. In this case an engine with two drums is required, of which there are two styles; one in which both drums are mounted side by side on one shaft, and the other in which the drums are mounted on separate shafts, tandem fashion, the back drum being elevated sufficiently so that the rope from this will not interfere with the forward drum. The special conditions of the problem will govern the choice of engine in most cases, but the tandem drum arrangement is generally preferred where the operating levers are attached directly to the drums.

ENDLESS ROPE HOIST-CONVEYORS.

Owing to the steep inclination necessary for the successful operation of inclined hoist-conveyors their application is confined to locations where the conditions are favorable. Where the inclination is not sufficient for the carriage to descend by gravity, or if the terminal points are upon the same elevation, the movement of the carriage is effected by means of an independent rope and drum.

An engine with two drums, therefore, is employed, as illustrated on the opposite page, in which the wider grooved drum is for the hoisting rope, and the narrower one for the endless hauling rope. The latter has an oval or elliptic grooved periphery, around which the rope is lapped a sufficient number of times to give the necessary frictional contact. Sometimes the endless rope is driven from a drum with spiral grooves, the rope moving from one side to the other as the carriage travels back and forth,

Hoist-Conveyor used in construction of the new dam across the Connecticut River at Holyoke, Mass. Built by THE TRENTON IRON COMPANY, Trenton, New Jersey. Span, 1,615 feet.

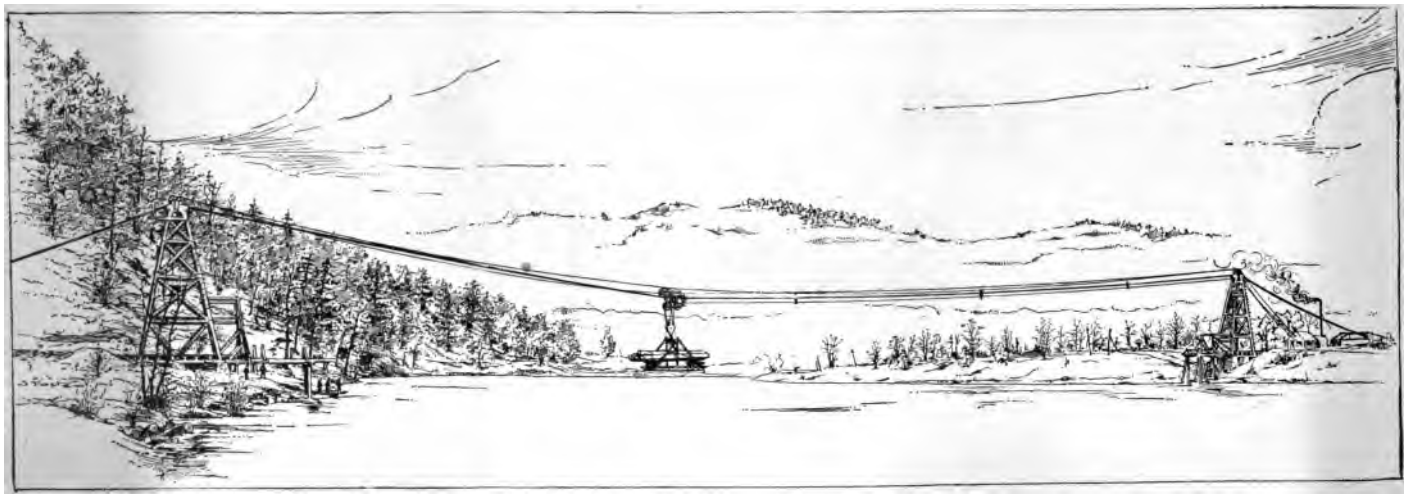
an arrangement manifestly adapted only to comparatively short spans. The drums are provided with brakes as well as power connections, so that each can be operated independently of the other. In moving the carriage back and forth both drums are put in motion, the hoisting rope coiling up or paying out, as the case may be, at an even rate with the hauling rope. In raising or lowering the power is disconnected from the hauling drum and the brake applied, holding the carriage at the desired point, while the hoisting drum alone is operated. The hoisting or lowering is done at a speed corresponding to the number of times the hoisting rope is rove about the sheaves in the carriage and fall block, the speed being inversely proportionate to the number of parts.

Carriers are provided for supporting the hoisting rope, the arrangement being such that these are spaced at regular intervals along the line as the carriage is moved out and gathered in again as it is brought back.

A great advantage which these hoist-conveyors possess is, that loads may be raised or lowered at any point under the line.

We present an illustration showing an interesting line used in the construction of the Connecticut River dam at Holyoke, Mass. The clear span is 1,615 feet, the longest yet made by any hoist-conveyor, and the line is capable of handling loads of 6½ tons. The illustration shows a foreground view of the Holyoke end, where the line crosses the main Holyoke canal and the Boston & Maine Railroad. The tower on this side is 120 feet high. On the opposite or South Hadley Falls side the tower straddles a water power canal, and is 100 feet high. The main cable is a 2-in. patent locked-wire steel rope, which is adjusted by means of special tackle blocks and a ⅞-in. steel wire rope of the ordinary lay, and each end is anchored to solid rock. The line handles all the stone and cement at a rate to employ three gangs of 15 to 20 men each.

The adaptability of the system for handling heavy loads is best exemplified in a line for transporting lumber across the Susquehanna River at Glen Union, Pa. The loaded cars, weighing from 12 to 15 tons, are taken across in a wrought-iron lattice-work cage, 36 feet long, the platform of which consists of a section of track, the rails of which abut with those of the tracks on each side of the river. The cage is



HOIST-CONVEYOR,

Carrying fifteen-ton loads across the Susquehanna River at Glen Union, Pa. Clear span, 735 feet.

Built by THE TRENTON IRON CO., of Trenton, N. J.

raised sufficiently to clear the water in transit. The accompanying view (from a photograph) shows the cage with a loaded car on it above mid-stream.

These hoist-conveyors are used quite extensively in the construction of the Chicago Drainage Canal, the towers being mounted on trucks so that the entire line can be shifted as the work progresses.

We also build lines to meet the special reqirements for light and rapid work, which can be quickly taken down and set up again in new locations, and such lines have contributed perhaps more than anything else to the economical working of the phosphate deposits of Florida.

A patent hoist-conveyor of this order, with self-filling bucket, has lately been introduced by us. It is the invention of Mr. James R. Hall, of Atlanta, Ga., and was employed by him in the excavation of the Suwanee Canal. The following account of it is from a recent article in the "Engineering News":

THE HALL PATENT EXCAVATING HOIST-CONVEYOR.

As shown in the illustration, a mast is mounted upon skids alongside one bank of the canal, and another mast is erected firmly in the ground on the opposite side, about 200 feet distant. If a tree is convenient it may take the place of the latter mast. These two masts constitute the supports for the stationary carrying cable, serving as a track for the hoist carriage, through which the operating ropes are rove, and below which the bucket hangs. They are secured by guy ropes to stumps of trees or buried logs, commonly known as "dead-men." For convenience of description we will call the mast on the skids the power-station mast, and the opposite one the spoil-bank mast. The skids upon which the power-station mast is mounted consist of a couple of long, heavy timbers, and the mast is erected near one end of these at a point where two cross-timbers intersect or are framed into the skids, one at right angles and the other parallel with them, forming a cruciform base, to which is secured four short guy ropes, used to steady the power-station mast during the operation of shifting from one position to another, which will be described later. At the other end of the skids is mounted the engine and boiler for operating the line.

Hall Cable Excavator and Conveyor. At work on the Suwanee Canal.
THE TRENTON IRON COMPANY, Trenton, New Jersey, Builders.

One end of the carrying cable, which is 1⅛ in. diameter, is fastened to a ring at the top of the power-station mast, and the other end, after being passed through a block attached to the top of the spoil-bank mast, is secured by a hemp rope tackle to a dead-man, tree, or stump. The hemp-rope tackle serves the purpose of stretching the carrying cable to the proper tension for work, or letting it out during the operation of shifting.

The preferred form of engine is one with double cylinders, three drums placed tandem fashion, and an upright boiler, all mounted on one bed-plate. The drums are set at slightly different elevations, or in steps, as in the usual arrangement of hoisting engines of this type, the back drum being the highest and the forward drum the lowest, in order that the ropes from the middle and back drums may not interfere or come in contact with the drums over which they pass. The drums are driven independently of each other through friction connections, operated by hand levers, and are also fitted with brakes operated by treadles.

The rope from the back drum which is used in the operation of loading the bucket and is known as the loading rope, A, (see illustration on following page) passes through a block at the top of the power-station mast, thence through a similar block anchored to a dead-man in the bottom of the canal, at a point some distance from the cable line, and thence to a fastening on the bail of the bucket. The rope from the center drum is used for hoisting, also for hauling in from the spoil-bank, and is known as the hoisting rope, B. It passes through a block at the foot of the power-station mast, and thence around a sheave in the hoist carriage to a fastening on the bail of the bucket. The rope from the forward drum is used in hauling the carriage out to the spoil-bank, and is known as the out-haul rope, C. It passes first through a block at the foot of the power-station mast, thence between idler wheels in the hoist carriage to a block at the top of the spoil-bank mast, through this to a block attached to the carriage, and thence to a link on the bottom of the bucket in the middle of one side.

The carriage consists of a pair of iron side plates, between which are two upper sheaves that traverse the carrying cable and a lower sheave

around which the hoisting rope passes. The block, through which the out-haul rope passes, is attached to the hook-link.

The bucket tapers from the top down, and in shape is that of a truncated wedge. The bail is rigidly fastened to the body, and the link to which the end of the out-haul rope is fastened, as already stated, is at the bottom edge in the middle of one of the flat sides, the position of which is quite important, as will be better understood when we describe the operation of dumping. The upper plates on the flat sides are of crucible steel drawn to a knife edge, so that the bucket may plough or cut its way readily through the material to be excavated.

The operation is as follows: Starting with the bucket in the bottom of the canal, directly under the cable line, and lying on one of its flat sides (it matters not which), the loading rope is put into action dragging the bucket horizontally along the bottom until it scrapes itself full, when the engineer places his foot gently upon the treadle connecting with the brake of the loading drum, throwing out the power friction at the same time, and applying power to the hoisting drum, also just enough power to the out-haul drum to keep up the slack of the out-haul rope. The object of applying the brake to the loading drum is to bring the bucket into a vertical position before hoisting, and thus prevent the load spilling. As it comes back under the line, the engineer releases the brake on the loading drum, and allows the loading rope to run slack. The bucket is raised sufficiently to clear the bank and obstacles under the line, when the engineer applies the brake to the hoisting drum, simultaneously throwing out the power friction on the same, and applying power hard to the out-haul drum. The bucket moves out above the spoil-bank and continues to rise at the same time, by reason of the hoisting rope being held taut, which is necessary to keep the bucket from turning upside down. When the bucket reaches the desired elevation, it engages a latch and the brake on the hoisting drum is released. A bumper on the carrying cable stops the carriage and prevents the bucket from dropping in the act of discharging. When the carriage reaches a point within two or three feet of this bumper, the steam is shut off from the engine, the power being still applied to the out-haul drum, and the brake taken off the hoisting drum, when the bucket swings back and at the same time turns

upside down. It does so with a jerk which very effectually clears it of its contents, but, to insure a good discharge every time, it is important that the bucket should fall flat side horizontal, and hence the reason for placing the link to which the out-haul rope connects, in the middle edge of one of the flat sides. After dumping, the power is taken off the out-haul drum and the brake gently applied; the steam is turned on, and power applied to the hoisting drum. When the bucket reaches a certain point the power on the hoisting drum is taken off, the bucket drops, and at the same time moves forward, till it reaches the center of the canal, when a bumper on the carrying cable similar to the one over the dump arrests the motion of the carriage, and the bucket drops vertically into the canal. During this operation sufficient power is applied to the loading drum to take up the slack of the loading rope.

If it is desired to land the bucket for loading at a point not directly under the line, but some distance from it in a direction opposite to that in which the bucket is dragged in loading, so as to get a longer pull on it, which is frequently necessary to obtain a full load, especially after most of the loose material has been removed, it can be done in either of two ways.

First: The empty bucket is brought to a point within a few feet of the bottom of the canal, when the brake is applied to the hoisting drum and power to the loading drum, bringing the bucket up to a position where the hoisting rope makes an angle of about 45° to the vertical. The loading rope is then released, and the bucket swings back through the canal to the opposite side of the cable line, and upon reaching the extreme point of oscillation, the brake of the hoisting drum is taken off, and it drops to the bottom in the desired position for loading.

Second: By attaching a hemp rope to the link on the bottom of the bucket, passing it through a block anchored in the bottom of the canal on the side of the cable line opposite in direction to that of the loading rope block, and thence to a winch-head on one end of the hoisting drum shaft, and by this means hauling the bucket back to any desired distance within the reach of the other ropes. A plough is used in breaking up the bottom after it has become too hard for the bucket to fill easily.

The operation of shifting the apparatus from one position to another is performed in the following manner: The bucket is first deposited on the spoil-bank, and all the ropes lowered to the ground, the carriage having been previously placed so that it will drop in a convenient spot for oiling the bearings and otherwise overhauling it. The guy ropes are all loosened, the blocks in the bottom of the canal removed, the loading rope detached from the bucket, and pulled entirely out of the blocks through which it is rove. Before loosening the ground guys, the shorter guys which anchor to the ends of the cross-timbers, at the base of the power-station mast are tightened. The ropes and tail block through which the out-haul rope passes are then disconnected from the spoil-bank mast and anchorage, and attached to a similar mast and anchorage, about fifty feet further on. A couple of blocks are attached to a dead-man about fifty or sixty feet ahead of the power-station mast, and a couple more to the skids near the foot of the power-station mast. Through these blocks the loading rope is rove and the end properly secured. Power is then applied to the winding up of the loading rope, and the whole rig on the skids moves slowly forward. The distance moved at each shift is usually about twenty-five feet, two shifts of the power-station mast being made to one of the spoil-bank mast. The dead-men or stumps serving as anchorages for the various guys and blocks are prepared in advance while the work of excavation is going on. After the power-station is moved, the loading rope is rove again through the blocks at the top of the mast, and in the bottom of the canal (the latter having been moved ahead to the anchorage prepared for it), and the end attached to the bucket as before. The mast guys are securely fastened to the anchorages prepared for them and hauled up tight; and, finally, the carrying cable is stretched into position, lifting the carriage and other ropes with it, and the work of excavating is resumed.

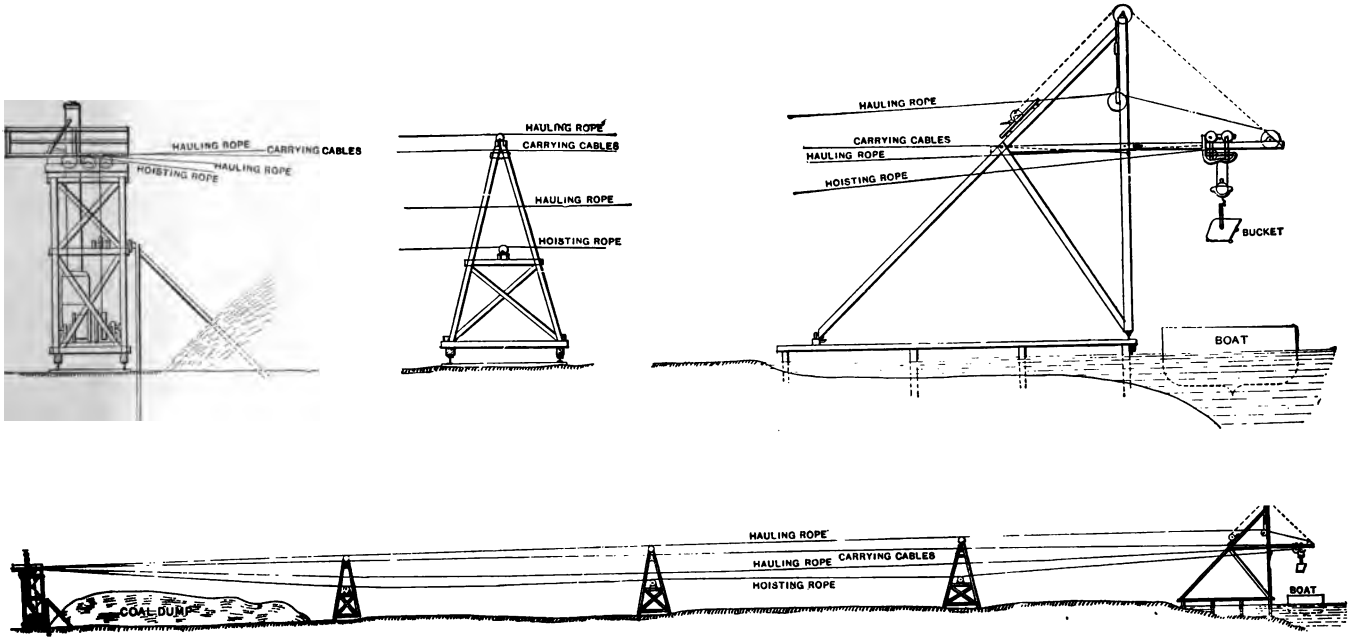
The operation of shifting requires from one to one and a half hours; and out of eleven working hours, three are consumed, on an average, in moving, oiling, making repairs, &c. The operation requires one engineer, one fireman, one helper, and one other man who watches the bucket, signals the engineer and attends to other duties. A couple of men are employed in setting masts and preparing anchorages for the successive moves. The output is from 250 to 300 cubic

Cable Excavator and Conveyor built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Harqua Hala Gold Mining Company, Harqua Hala, Arizona.

yards per day for each line, according to the nature of the materials. The cost of operating is about $12 per day, including fuel and oil, or, taking everything into consideration, the cost is about six cents per cubic yard. With more favorable conditions than those encountered in excavating the Suwanee Canal, conditions, for instance, conforming to a larger output and cheaper fuel, it can readily be understood how the cost might be reduced materially.

A modified form of the Hall rig was built for the Harqua Hala Gold Mining Company, of Harqua Hala, Arizona, to work a bed of tailings, as shown in the accompanying view. This bed, including both the old and new tailings, covers a considerable and irregular area of ground, there being about 120,000 tons to be delivered to the leaching vats, at the rate of 150 tons per day, representing about three years' work. The problem was not only to hoist and convey this amount of material, but to build a line that would also be self-digging and portable; or, in other words, a line with a self-filling bucket, and with supports that could be moved radially about a stationary end support at the leaching vats; so as to work over the whole area without requiring hand labor. A further condition was that the line must be adapted to work in varying lengths, on account of the irregular shape of the bed, the longest distance being 825 feet.

The main trackway for the carriage consists of a $\frac{7}{8}$ in. steel patent locked-wire cable laid double; that is, at the stationary end tower, just behind the bins near the leaching vats, it passes around a sheave in a shackle, which is securely connected to a ground anchorage, and is stretched over the two end towers and intervening supports in two parallel lines; one end of the rope is rigidly fastened at the back of the movable end support, and the other end is coiled on a drum worked by a ratchet, sufficient cable being provided so that it can be paid out or wound up on this drum to suit the varying lengths in moving to different positions. The movable end support is firmly secured by guy ropes to posts. Below the carriage hangs the bucket of one-ton capacity, which is identically the same as that used on the Hall rig, and is operated by three ropes in a similar manner. The loading rope in this case, however, works parallel with the main cable instead of at right angles to it. This rope is attached directly to the bail of the bucket, and the main cable therefore is relieved from all strain during



Hoist-Conveyor built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for loading and unloading vessels.

the operation of loading, which is the heaviest part of the work. The three ropes pass over sheaves at the top of the stationary tower in a pivoted shackle, which accommodates itself to the different angles at which the ropes must work, these ropes only being affected by the varying lengths of the line so far as to alter the amount of unused portions on the drums. How successfully the line does the work is best told in the words of R. M. Raymond, the manager of the Harqua Hala Mines, and under whose direction the line was built. In a letter dated August 13, 1895, Mr. Raymond says: "We consider the tramway most satisfactory and a great success. Nothing could suit our purpose better, and we are now able to run it up to full capacity. The way it gets down and digs in the sand is fine, and the whole arrangement is complete. It is so near being alive that if the engineer could be dispensed with and an automatic arrangement devised to keep the thing going, it would be the most wonderful hoisting arrangement in the field."

HOIST-CONVEYORS FOR LOADING AND UNLOADING VESSELS.

We present an illustration of a plant specially designed for stocking coal yards from masted vessels at a dock. Two patent locked-wire cables—$1\frac{1}{8}$ in. diam.—are stretched between the terminal structures and over intermediate supports about 100 feet apart, and constitute the trackway for the hoist carriage. The terminal structures and supports may be so mounted that they can be moved, or they may be permanent affairs, as desired. The main cables are anchored securely at the dock terminal, and at the yard terminal are wound on drums operated by a ratchet and lever, the latter being provided in order to relieve the cables of tension when shifting from one position to another. If the line is a fixture, these drums may be replaced by counterweights. The yard terminal structure supports the engine and boiler by means of which the line is operated, the engine being similar to that used on other endless rope hoist-conveyors.

In its special application to the unloading of coal, self-dumping buckets are used of the ordinary type, such as used in derrick work. There are two buckets in an outfit, each capable of holding a ton of coal, one being loaded while the other is taken over to the yard and back.

Floating Hoist-Conveyor built by THE TRENTON IRON COMPANY, Trenton, New Jersey.
View Showing Machine Boat.

The boom at the dock terminal is hinged in such a way that it can be raised by a winch, provided for the purpose, in order to clear the rigging of the vessels while these are coming in or departing.

We illustrate another hoist-conveyor designed especially for stocking the sugar plantations of Louisiana with coal. The general arrangement and method of operation are similar in some respects to the dock hoist-conveyor above described, but in this case everything is designed for a floating rig, which is moved about from one plantation to another. The main structure consists of a frame tower, which, with the operating mechanism, is mounted upon a barge, designed expressly for the purpose, as illustrated on page 70. In setting up the line it is necessary at times to take into consideration the matter of a current flowing at the rate of five miles per hour, and a rapidly rising and falling stage of the water, conditions which have been successfully met.

Everything at the outset is so stowed on the machine boat that each piece can be readily made fast to the drag chain in the order required, and the setting up of the line is accomplished with great celerity. At the location shown on page 70 the machine boat lay 400 feet out in the stream from the levee, two stretches of water filled with drifts and stumps and the remnants of an old levee intervening. The distance from the levee to the end mast was also 400 feet, making a total run of 800 feet. A round trip can be made over this distance in less than two minutes, or, in other words, the line is capable of a daily output of 350 to 400 tons.

A special type of inclined hoist-conveyor used extensively on the California and Hawaiian coasts is shown in the view of the line at the Gualala Mills Landing, Gualala, Cal., which also shows in the background the old style of derrick chute which has given place to the wire cable system.

The anchor for the main cable, weighing about 5,000 lbs., is attached to some 300 feet of 2-inch chain, and this chain to about 250 feet of 1½-inch galvanized iron rope, which is attached to the main cable by means of a hook and eye coupling. When shipping is interrupted for any considerable time, the ropes are uncoupled and the main cable coiled up on a drum at the shore landing. At such times the chain and iron rope lie in the bottom, with a light chain extending from the latter to a buoy, so that the end of the rope can be picked up

Floating Hoist-Conveyor built by THE TRENTON IRON COMPANY, Trenton, New Jersey.
View of Tail Post.

again when wanted. As a precaution against accidents to this chain, a similar chain and buoy are attached to the heavy 2-inch chain. The anchor lies in about 15 fathoms of water, and the vessel in about 12 fathoms. In the busy season the main cable is not taken in when a vessel gets through loading, but the two ropes are coupled together and cast off. Another vessel coming, picks up the ropes, uncouples them, passes the ends between the masts and couples them again; the main cable is then drawn up to a proper distance in the rigging, and the conveyor is ready for operation. Means for imparting the proper tension to the main cable are provided at the shore landing. Means are also provided here for holding the carriage while raising or lowering, and a grip or latch on the carriage itself prevents the load from falling in transit. The operating drum is mounted on an elevated stage or floor, which gives the brakeman an uninterrupted view of the entire line. Loads up to one ton in weight are carried, and the time of a round trip is two minutes, including time of loading and discharge, which corresponds to an output of 30 tons an hour. The carriage travels at a good speed down to the vessel, notwithstanding the fall is but 45 feet in a run of 550 feet.

Hoist-Conveyor at Gualala Mills, California, for loading vessels in open roadstead.

HOIST-CONVEYORS, BUILT BY THE TRENTON IRON COMPANY.

FOR WHOM.	LOCALITY.	Number of hoists.	MATERIAL HANDLED.	Length of span, in feet.	Capacity in tons, individual loads.
Arnold & Stephens	Tilly Foster, N. Y	1	Iron Ore	600	10
Cobb Lime Co	Rockland, Me	1	Lime Rock	680	6
" " "	" "	1	"	450	1
" " "	" "	1	"	750	1
Ideal Lime and Stone Co.	Texas, Md	1	"	1,000	5
" " " "	" "	1	"	450	5
Cornelius Hanrahan, Mgr	Rockland, Me	1	"	865	6
Glen Union Lumber Co	Glen Union, Pa	1	Timber on R. R. cars.	735	15
Dunnellon Phosphate Co	Ocala, Fla	1	Phosphate Rock	700	1½
Passaic Quarry Co	Avondale, N. J	2	Brownstone	400	10
Fred. Kocher & Co	" "	1	"	250	3
William Downs	New York City	1	Phosphate Rock	550	1
Empire State Phosphate Co	Rock Mines, Fla	6	" "	500	1
Linley & Co	Buenos, Ayres, Argentine, Rep., S. A.	1	Coal	400	1
Manufacturing Investment Co	Madison, Me	1	Limestone	265	¼
F. W. Bird & Son	East Walpole, Mass	1	Paper	350	3
Kerr Brothers	Wiightsville, Pa	1	Limestone	800	3
Avondale Lime and Stone Co	Avondale, Pa	1	"	900	5
Hubbard & Macduff	Ocala, Fla	3	Phosphate Rock	400	½
Dennis Long & Co	Louisville, Ky	1	Iron, &c	790	5
Desforges & Jung	New Orleans, La	1	Coal	800	1
John Kellar	Lancaster, Pa	1	Stone	550	1
Coleman, Ryan & Brown	Croton Landing, N. Y	2	"	1,200	5
Wentworth Gypsum-Co	Windsor, Nova Scotia	1	"	1,009	5
Crawford & Dugan	Audenried, Pa	1	"	875	6
Fruin-Bambrick Const. Co. / H. S. Hopkins	Holyoke, Mass	1	"	1,615	6
U. S. Government	Britts Landing, Wis	1	"	850	5

The Application of Wire Rope

TO SHAFTS, INCLINED PLANES, AND MINE HAULAGE.

Wire rope will always be an important factor in all mining operations, and its widest application, perhaps, is to be found in its adaptation to the surface and underground haulage of coal and ores. Animal power may continue to be employed to a greater or less extent in some mines, but it is rapidly giving way to improved wire rope appliances, and this must necessarily be so as the workings become more extended, and the matter of haulage becomes a serious item in the economical working of the mines. The ease with which wire rope can be led in any direction, and over any grades, its comparative safety, high efficiency, and the freedom its use procures from the smoke and gases generated by the use of steam motors, has brought it into almost exclusive use for conveying coal and ores from the interior of mines to the surface or place of shipping.

The conditions attending its application in different localities are so varied that space will permit us to consider only the main features of those systems which have come into general use. These may be grouped in three different classes: Shafts, Inclined Planes, and Haulage. We will consider the different adaptations in the order named.

SHAFTS.

The term shaft applies to vertical or inclined passageways through which the materials are raised or lowered in cages or skips. The application to vertical shafts covers the ordinary forms of elevators, which are so familiar to most people that few words will suffice on this subject.

HOISTING APPLIANCES.

The ordinary arrangement comprises two cages, operated by a reversing winding engine at the shaft-head. The ropes are led over head-sheaves from 6 to 18 feet in diameter, and are attached by means of sockets to the cages supporting the cars.

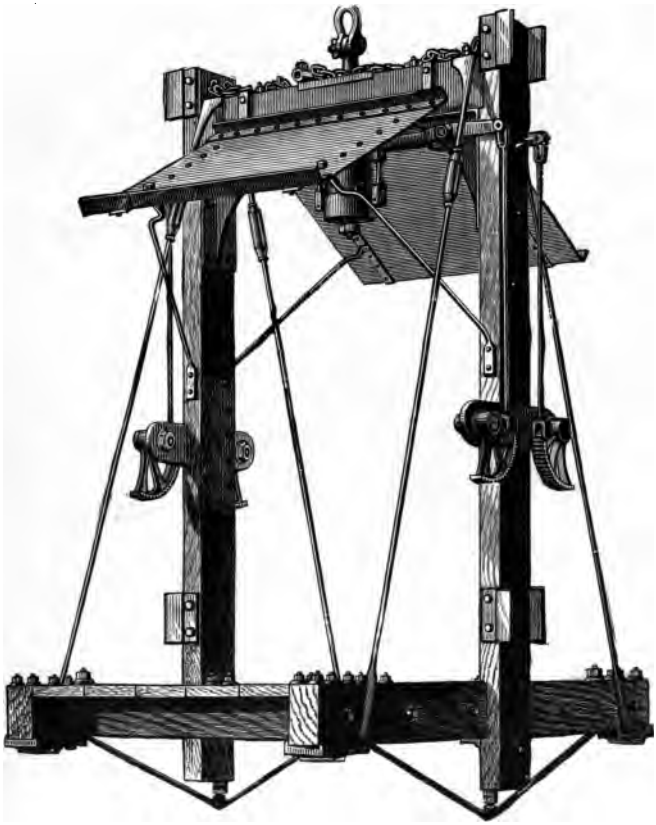


Fig. 1.—Elevator Cage.

Fig. 1 illustrates a common form of cage used in the coal regions. The guide bars on the posts between which the cage works are usually

Front Elevation.

Self-Dumping Elevator Cage.

Side Elevation.

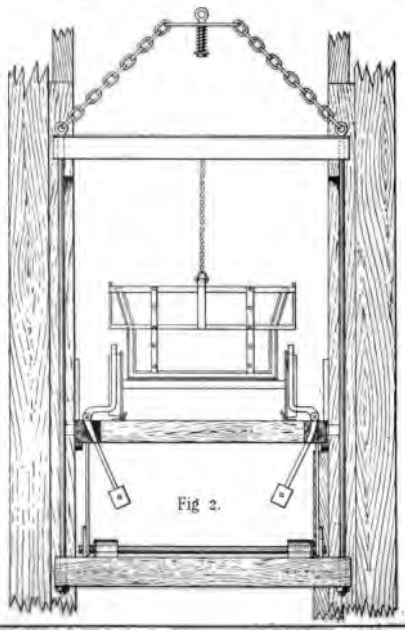


Fig 2.

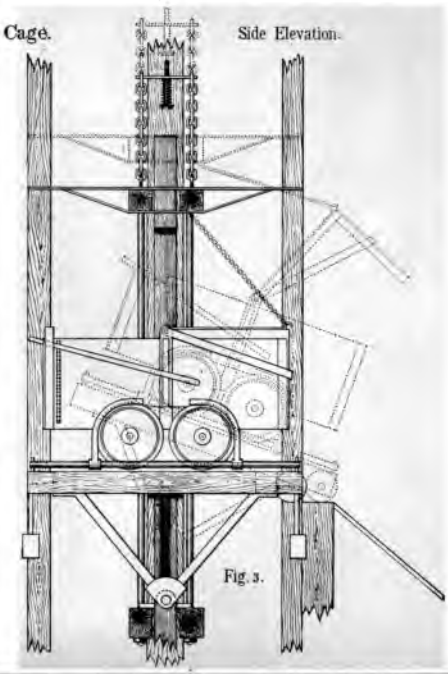


Fig. 3.

of wood, and in order to guard against accidents in case of the rope breaking, the cage is provided with safety catches, the action of which is such that the instant the tension is released, as it would be in case of a break, the toothed cams shown at the side of the cage imbed themselves in the guide bars, and thus arrest the descent of the cage.

The cages should always be equipped with "safety hooks." In case "overwinding" should occur, due to the carelessness of the engineer or accident, these hooks simply detach themselves from the rope, leaving the cage suspended in the upper guides, while the loose rope-end merely winds around the drum, thus avoiding the wrecking of the cage and destruction of the whole head-gear of the shaft.

The engine drums are either plain or grooved iron cylinders, or iron rims lagged with wood, the relative merits of each depending on the conditions under which they are operated. In many mines, especially where the shaft is of considerable depth, the engine drums are made conical. The ropes are attached to the small ends of the drums, the one winding while the other unwinds. These are called "fusee" drums, and possess the advantage of a diminishing leverage in hoisting opposed to an increasing leverage in lowering, so that the effort in starting is gentle, and the work done by the engine more uniform. The same advantage pertains in a greater degree to the use of flat ropes, which are coiled on reels, and which possess the further advantage of always working in the same direct lines, giving steadier motion to the cages. In many of our deepest shafts, where rapid hoisting is desirable, these ropes are preferred on this account. It is advisable, however, with flat rope, to use a larger factor of safety than with round rope of equal strength, and the proportion between their weight for equivalent working strength is about as 7 to 5 in favor of round rope.

In many European mines this objection is obviated by the use of taper ropes, which are said to give very good results with a minimum of dead weight.

The engine drums are sometimes driven from the engine shaft through a pinion and gear-wheel, although in most mines direct-acting engines are now used, or engines in which the connecting rods are coupled direct to the drum shaft.

Where it is desired to deliver the coal or ore at the shaft-head without further handling, an automatic-dumping cage, similar to that

Skip Hoists.

Fig. 4.

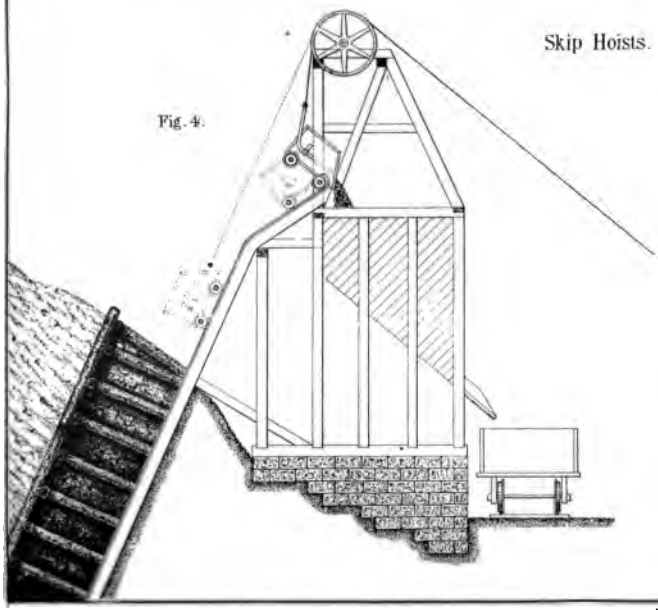
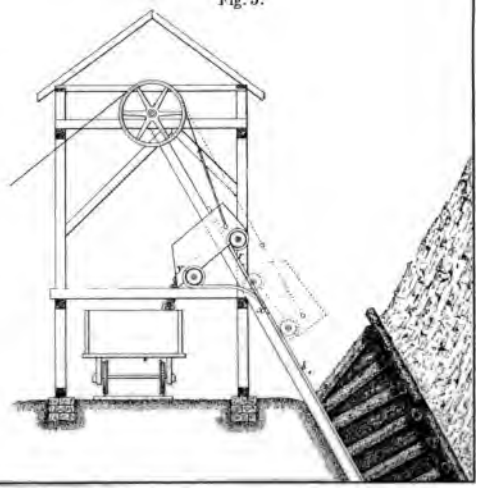


Fig. 5.



shown in Figs. 2 and 3, is used. By this arrangement the material is dumped on to the screens or chutes, as the case may be, without the car leaving the cage. The cage is shown at the point just about to tilt, the position in the act of tilting being indicated by the dotted lines.

SKIP HOISTS.

Where the shaft is a very steep incline, the materials are hoisted in peculiar-shaped cars called skips (shown in Figs. 4 and 5), and such shafts are commonly known as skip hoists. At some mines these cars are called "gunboats," and are made to hold from 3 to 5 tons. Fig. 4 illustrates the arrangement at one of the mines of the Lehigh Zinc and Iron Co. The skip is provided with a bail composed of two side bars crooked at their lower ends, and hinged to the sides of the skip near the lower corners. The upper ends of these bars are connected by a square bar with round ends, to which the chain at the end of the rope is attached. The rope passes over a head-sheave at the top of the framework to the engine. For a short space at the shaft-head the track bends down to a lighter inclination, and the ends of the rails are turned up to fit the wheels of the skip. When the front wheels reach these turned-up ends, the engineer is signalled to hoist slowly, lifting the back end of the skip off the track sufficiently to discharge the load into bins or cars. The engine is then reversed and the skip runs back into the mine.

Another arrangement is illustrated in Fig. 5.

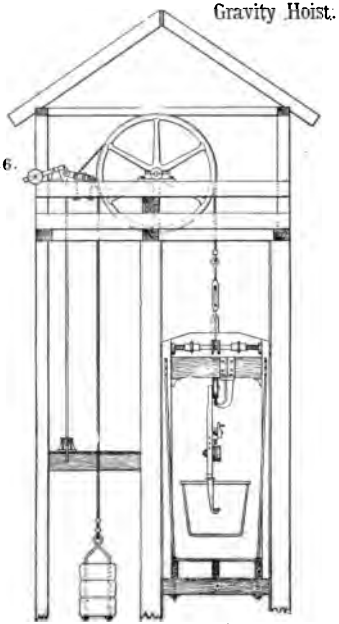
The skip is constructed with one set of narrow-tread wheels in front and a set of double width of tread in the rear. When the skip arrives at the shaft-head, the front wheels run on to the bent portion of the track, *b*, passing between the rails, *r*, extending from *x* to *y*, while the rear wheels, on account of their broad tread, reach the rails, *r*, and continue on to the proper height for tipping and dumping the load.

GRAVITY HOISTS.

When the load is a descending one, gravity may become the motive power, and the cages operated by means of brakes applied to

Gravity Hoist.

Fig. 6.



Front Elevation.

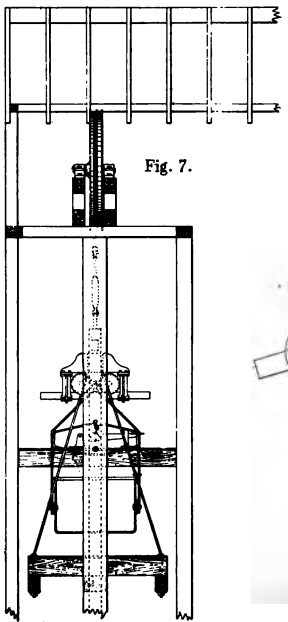


Fig. 7.

Side Elevation

Rim of Head Sheave

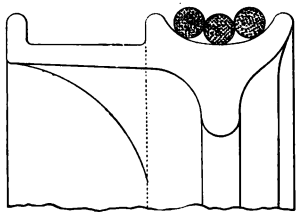


Fig. 8.

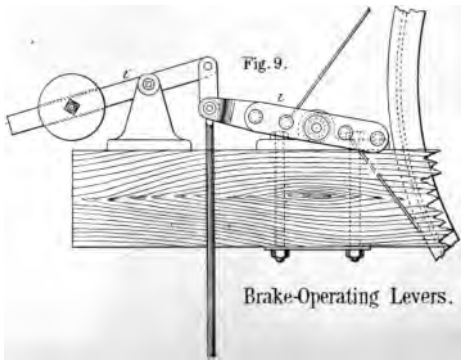


Fig. 9.

Brake-Operating Levers.

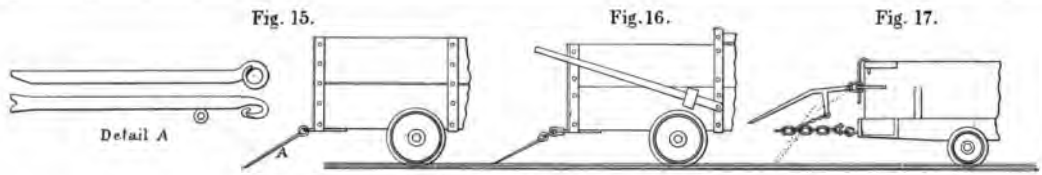
the head-sheaves. An arrangement of this kind, illustrated in Figs. 6 and 7, was recently built by us for the Solway Process Company, of Syracuse, to deliver limestone from the upper benches of a quarry to the loading bins of a Bleichert wire rope tramway.

The head-sheaves are fitted with brakes, and the grooves in which the ropes work are made elliptical in shape, as shown in Fig. 8. The rope in each compartment is given three laps about the sheave, which is sufficient to prevent slipping. Counterweights are provided, as shown, which are heavy enough to lift the cage with the empty car, and light enough to be lifted by the cage containing a loaded car. The arrangement of the brake-operating levers is shown in Fig. 9. The rod, *r*, attached to the levers, *l* and *l'*, extends to the bottom of the shaft, and by means of this the cages are stopped or started from any level.

INCLINED PLANES.

Inclined planes are of two kinds; engine planes, where power is used to raise the loads, and gravity planes, where the load itself is used as the motive power. Before considering the distinctive features of each, a few remarks in regard to track rollers, mine cars, tipples and some other features common to all inclined planes and other rope-haulage lines, will not be amiss.

The style and disposition of the track rollers for supporting the rope is an important consideration. Ordinarily they are of wood, from 5 to 8 inches in diameter, and from 16 to 24 inches long (Fig. 10), with $\frac{7}{8}$" or 1" axles. Gumwood, as a rule, is preferred. The bearings are generally mere blocks of wood, although for permanent work it is advisable to make them of iron. These rollers are spaced from 15 to 30 feet apart, the distance depending largely on the contour of the ground; the closer distances being observed on convex slopes, and the greater distances on straight grades and concave slopes. Steep slopes, with straight, even grades, require fewer rollers than those with lighter grades. On steep or concave slopes the distance between the rollers may often be from 40 to 50 feet, and if the concavity is greater than the catenary corresponding to the tension of the empty cars, the rollers

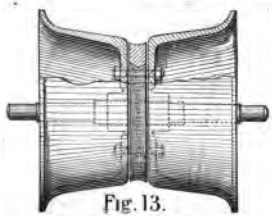


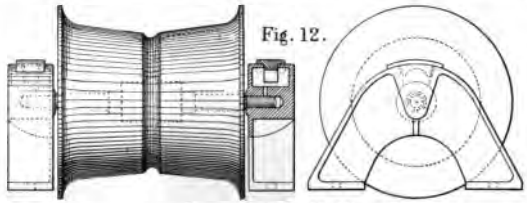
Various Styles of Growlers.

Ordinary Wooden Track Roller.

Wooden Track Roller with Iron Bands.

Iron Cylinder Roller.





Iron Track Roller.

Iron Track Rollers.

may be omitted altogether without detriment to the rope, as it lifts clear of the ground the moment it is under tension. It very frequently happens, in underground lines where there is a concave dip, that rollers have to be placed above the tracks to prevent the rope scraping against the roof of the gangway. In such cases iron rollers are generally used.

The expense of keeping up these rollers in long lines often amounts to considerable, and for this reason they do not always receive the best attention; but to neglect them is poor economy.

The rapid wear of the track rollers is a source of constant expense in the operation of any plane. If they are not kept in good repair, the rope soon begins to suffer. The irregularities of the surface of the ordinary kinds of rope is the chief cause of this rapid wear, which is always greatest when the rope is new; as the interstices between the rope strands become filled up and the outer wires worn down, the wear becomes less. The use of the patent "locked wire rope," which is perfectly smooth from the beginning, does away with all of this wear, and wherever it is used the life of the track rollers is extended indefinitely.

Fig. 11 represents a very good type of track roller. A wooden cylinder fits into iron rings at each end. The axle consists of a bolt with a collar at one end and a nut at the other, the ends being turned down. The hole in the wooden cylinder is large enough to allow the axle to pass through easily, but fits tightly in the iron rings at each end. On the inside of the end rings are ribs which imbed themselves in the wood when the nut is screwed up. These rollers not only give better service than the ordinary wooden roller, but as the cylinders wear out they can be quickly replaced by new ones. Although wooden rollers appear to meet with most favor, iron ones are preferred in many mines. Common forms of these are illustrated in Figs. 12, 13 and 14. Fig. 13 shows the same style of roller as Fig. 12, with a removable wearing ring. The roller is made in halves, which are bolted together at the center, and when a ring wears out it is a simple matter to replace it with a new one, thus saving the expense of an entire new roller. This style of roller is recommended for places where the wear is excessive. In going over sharp knuckles, the track rollers should be placed from three to four feet apart, or as close together as possible. An excellent thing at such points on inclined planes is the arrange-

FIG. 18.

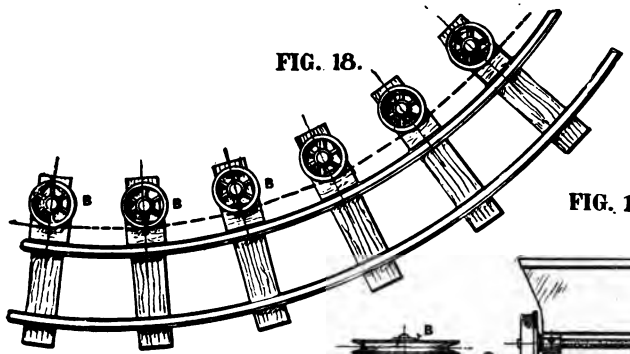
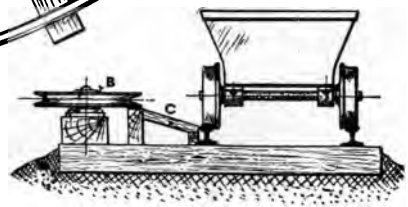


FIG. 19



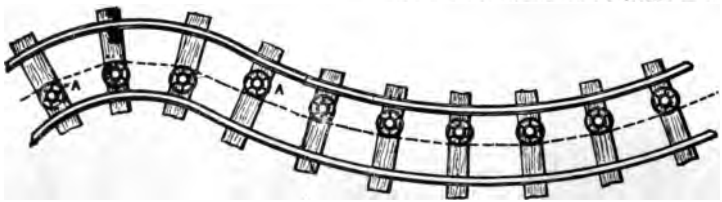


FIG. 20

FIG. 21

ment of deflecting and compensating sheaves devised by Eckley B. Coxe, of Drifton, Pa., and illustrated in Figs. 22, 23 and 24. The two sheaves are connected by friction-wheels, as shown, and as either one is moved the other is set in motion in the opposite direction. When the rope, traveling at a high rate of speed, strikes this sheave, it finds it already revolving at the exact speed required, and the heavy friction that with ordinary sheaves would be developed in setting them in motion is thus avoided. In guiding the rope around curves, iron rollers are generally employed, placed close together. The two methods in common practice are illustrated in Figs. 18, 19, 20 and 21. Where the rollers are between the rails, as in Fig. 20, they are from five to six inches in diameter, and usually secured in a slightly inclined position, as shown in Fig. 21. The axles of the rollers sometimes simply consist of pintles bolted to the ties, but they are generally secured to cast-iron base plates. Where space will permit, the arrangement shown in Fig. 18 is to be preferred, as it is easier on the rope. The sheaves in this case are just outside the track, are larger in diameter, and fewer in number.

MINE CARS, TIPPLES, ETC.

Mine cars are of such various sizes and patterns that it would be impossible to give details of more than one or two. The style represented in Fig. 25 is a type pretty often used in bituminous coal mines; where space permits, but where the entries are narrow, the box form shown in Fig. 26 is preferred. In the car shown in Fig. 25 the door is hinged at the top of the middle band. When the car is run on to the tipple, the upper band of the door catches in a hook, which opens the door in the act of tipping. Fig 27 represents a car without any door, the front end having an inclined board in the bottom, as indicated by the dotted lines, which occasions the loss of some space in the corner. In the car shown in Fig. 26 the door is hinged to a rod adjoining the tops of the front band. This necessitates a lock bar, which has to be knocked out as the car is run on to the tipple. The lumps of coal are more apt to clog in these cars than in those with doors hinged to the middle band. Sometimes the cars are furnished with brakes, as shown in Fig. 25. The manner of coupling the cars is

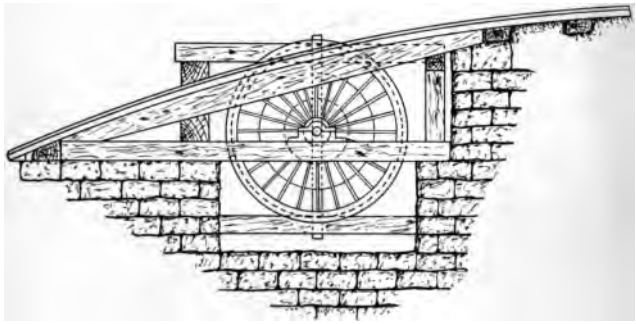


Fig. 22. Side Elevation.

Deflecting and Compensating Sheaves.

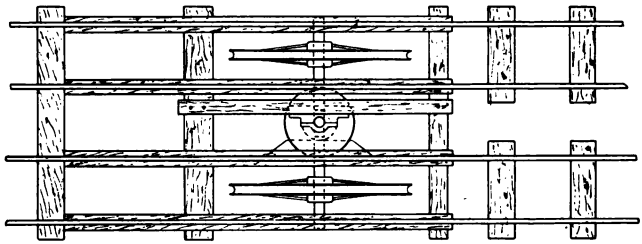


Fig. 23. Plan.

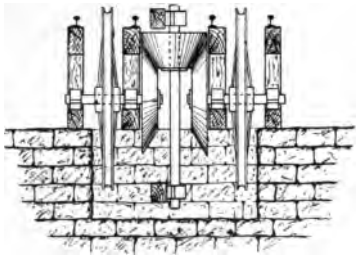


Fig 24. End Elevation.

a feature worthy of notice; the simplest coupling consists of a short chain, with hooks at each end, but it is more common to use clevises. Sometimes rigid bars are used, especially where the grades are such that the cars are likely to run together.

The attachment of the front car to the rope is usually made by means of a chain from 15 to 20 feet long, socketed to the rope, and provided with a clevis or hook. This chain saves the rope from kinking, owing to the end being tossed about more or less in attaching and detaching; and even when so provided this end of the rope will wear more rapidly than any other portion, so that as it gives out short pieces are cut off or the rope turned ends about and re-socketed. Description of sockets will be found on pages 143 to 147.

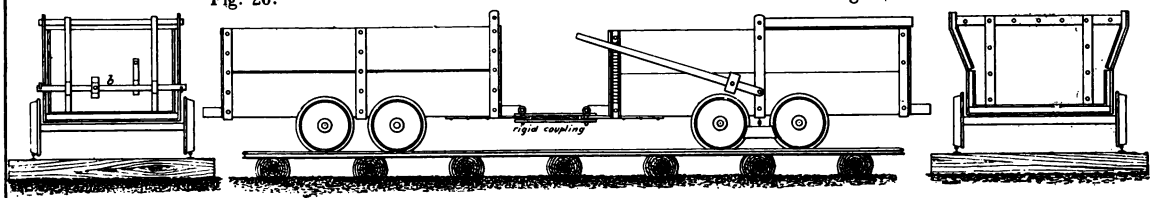
A few words in regard to tipples will not be amiss. The ordinary tipple consists simply of a small platform, pivoted and counterweighted in such a way that when the mine cars are run on to it, their weight overbalances the tipple counterweights, causing them to tilt and discharge over screens or crushers, into bins or cars, as the case may be. The rails on the tipple are turned up at the ends to fit the wheels of the mine cars, and hold them in place during the act of discharging.

Figs. 31 and 32 illustrate an arrangement of tipple, provided with a brake lever and ratchet, by means of which the cars can be dumped by the weighmaster. The counterweight beam, *c*, which is suspended from the front end of the tipple beam, *b*, hangs between two horizontal beams, *e* and *h*, the former being stationary, while the latter is hinged at one end. The opposite end of the beam, *h*, is attached to a rod that leads to the operating lever, *l*, in the weighmaster's office. This lever is provided with a ratchet and pawl, as shown, by means of which the tipple is securely held until the weighmaster is ready to tip. With this tipple, the coal, instead of being discharged in a mass suddenly over the screens, as with the ordinary tipple, may be dumped gradually, causing less breakage and giving a more thorough screening.

Figs. 33 and 34 illustrate a patent coal tipple, controlled in a similar manner, in which the cars are held in the act of dumping by a rod attached to a coil spring. This rod is hooked into the draw bar of the car. As soon as the car is dumped and has righted, the car is unhooked and shoved ahead over the tipple. A sharp inclination in the track at the end, in conjunction with an automatic switch, operates to

Fig. 26.

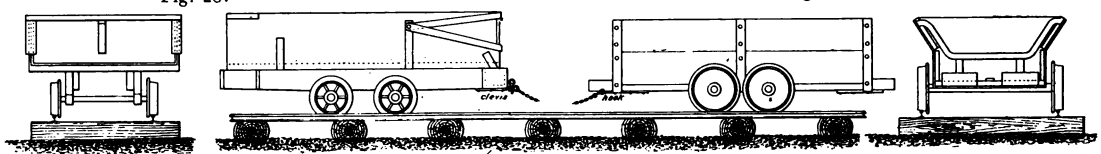
Fig. 25.



Various Styles of Mine Cars.

Fig. 28.

Fig. 27.



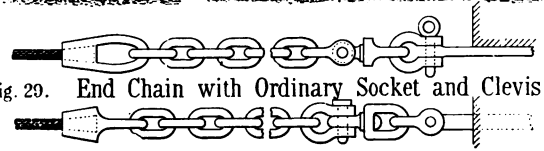


Fig. 29. End Chain with Ordinary Socket and Clevis.

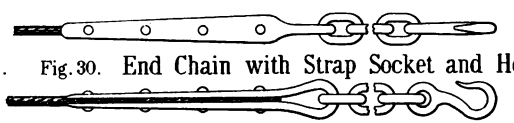


Fig. 30. End Chain with Strap Socket and Hook.

bring the car back on to a side track, the tracks being laid on a slightly descending grade. It is claimed that runs of 300 tons per hour can be made over one of these tipples by one man.

Most inclined planes are provided with safety devices of some kind to guard against accidents. Of these a variety have been devised, but all those depending on throwing the cars from the track by means of obstructions, mechanically placed on the track, are crude and unreliable. This may also be said of the safety switches, which, to be effective, are thrown into position by the engineer after the accident happens. The only reliable method is the automatic safety switch, which is always set to run the cars off on it, unless the operator holds it open while the cars pass down the main track, the ascending trains opening the switch automatically. A switch of this kind is shown in Fig 47. In gravity planes a block is frequently used in the center of the track, as a safeguard to prevent the cars running off on the incline before they are properly attached to the ropes. This block is counterweighted in such a way that it always projects up in the center of the track, and must be pressed down out of the way, when the cars are ready to descend, which is done by means of a lever at one side of the tracks. The best safety appliance for planes where the load is an ascending one, is the old-fashioned "growler," which consists of an iron bar about two inches square and from four to five feet long, attached to the draw bar of the last car, and which drags over the ground and track rollers as long as the cars are running ahead. In case of a breakage of rope or coupling chains, this bar, which is pointed at the end, is immediately driven into the ground, and thus prevents the cars from running back down the slope. In some mines this bar is called the "doctor"; in fact it goes by a variety of names. Several styles of these "growlers" are shown in Figs. 15 to 17.

ENGINE PLANES.

Engine planes may be either single or double ; in the latter case a double-drum engine is used. Non-reversing engines are usually employed, the drums being driven by friction, and fitted with brakes to control the descent of the empty cars. These inclines are often of

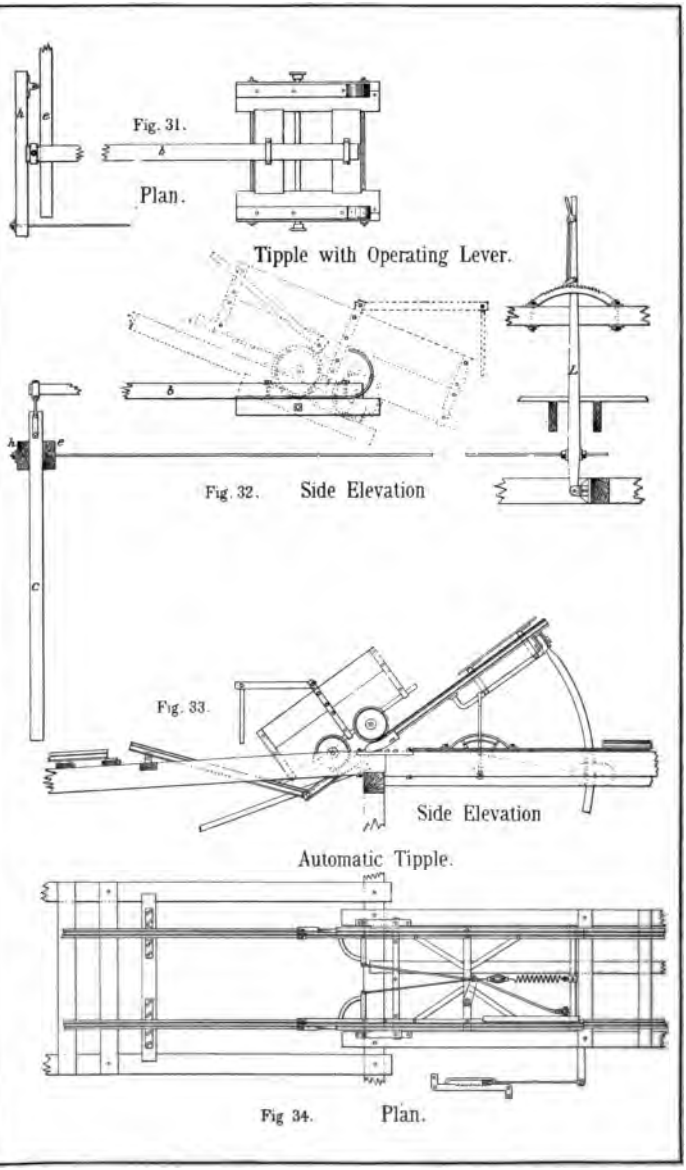


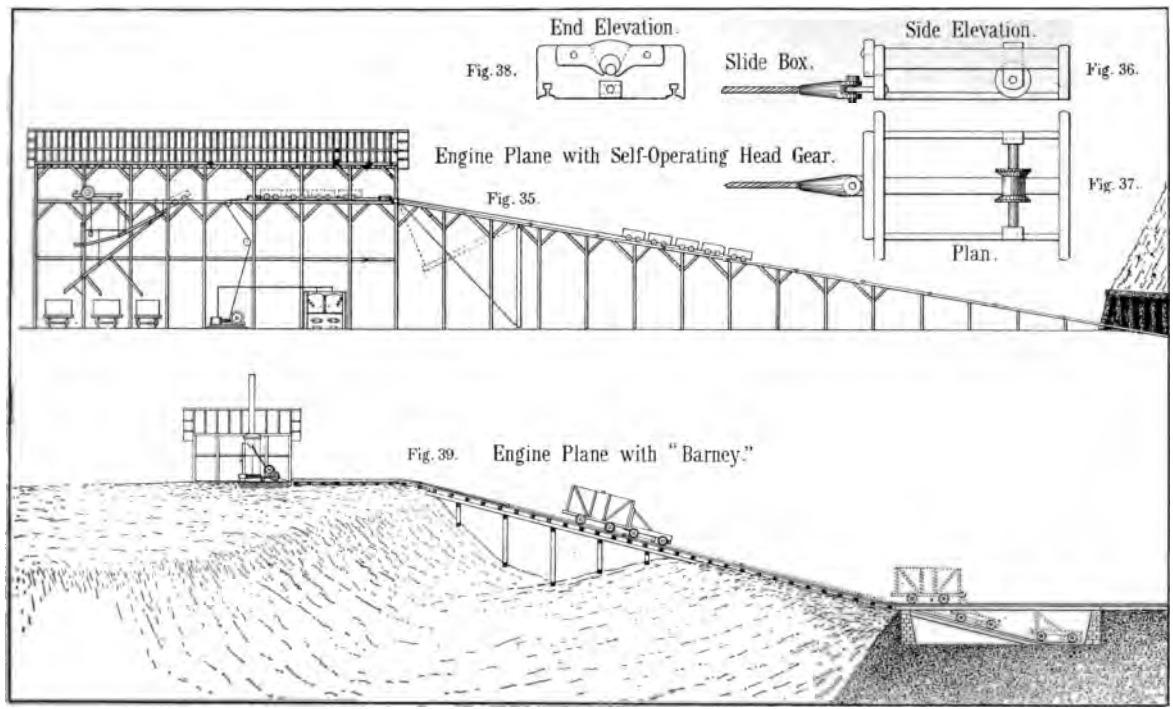
Fig. 31.
Plan.
Tipple with Operating Lever.
Fig. 32. Side Elevation
Fig. 33.
Side Elevation
Automatic Tipple.
Fig 34. Plan.

considerable length, with curves and varying grades. In cases where the grades at the upper end of the slope are too slight for the empty cars to start on, or where the tipple is located some distance back from the head of the slope, on a level track, it is advisable to adopt some mechanical method of starting the train, such as is employed on one of the mines of the Cahaba Coal Mining Company, at Blocton, Ala., and illustrated in Figs. 35 to 38. This is accomplished by means of counterweights or counterweight levers, which have previously been raised by the ascending train, and which in falling back start the returning cars.

Engine planes are frequently operated as shown in Fig. 39, in which the raising and lowering of the cars is done by means of a smaller car, known as the "barney," permanently attached to the end of the rope. The "barney" traverses a narrow track within the main track and drops into a pit at the foot of the slope out of the way. By this method of working the loss of time which occurs ordinarily in the coupling and uncoupling of the cars is avoided.

An engine plane may be adapted to work a series of side entries in a mine, as illustrated in Fig. 40. Each side entry has a parting at its junction with the main gangway for the accommodation of the trips in going in and coming out of the different entries, the empty cars being delivered to the various partings in succession, and the loaded cars standing on the opposite track taken out. A horizontal sheave is placed at each bend within a few inches of the track, to guide the rope around. By means of marks on the rope, or an indicator, the engineer is enabled to stop the "empties" alternately at the different junctions. A man passing from one junction to the other attends to the switches, attaches and detaches the rope, and gives the proper signals to the engineer.

Under ordinary conditions the minimum grade for an engine plane is about 3 per cent. On lighter grades than this the empty cars will not descend freely. There are so-called "inclined planes" where the grades are lighter, which are worked by means of an endless rope, but they should be classed more properly as types of the endless rope haulage system, and will be referred to under that head. While it requires a fall of at least 3 per cent. for empty cars to descend freely, loaded cars will descend much lighter grades. A train of twenty-five


End Elevation.
Fig. 38.
Slide Box.
Side Elevation.
Fig. 36.
Engine Plane with Self-Operating Head Gear.
Fig. 35.
Fig. 37.
Plan.
Fig. 39. Engine Plane with "Barney."

to thirty mine cars, for instance, holding a ton each, will descend a grade of 1¾ per cent., and in such cases where the grade is not sufficient for a "self-acting" gravity plane, an engine is required to haul up the empty cars. Inclines of this kind are frequently applied to the feeding of long lines of coke ovens, the latter being built on an incline sufficient for the loaded larry to descend easily; the engine simply acting to haul the larry back. A line of ovens at Blossburg, Ala., is fed in this way, the inclination of the tracks being 1 to 35, or a grade of about 3 per cent.

GRAVITY PLANES.

The ordinary arrangement of operating gravity planes is illustrated in Figs. 41 and 42, and consists of a drum at the head of the slope, located preferably below the tracks, as shown. Where space will not permit of this arrangement, the drum may be mounted in a frame above the tracks. The drum revolves on a horizontal axle, and the two ropes attached respectively to the loaded and empty cars coil and uncoil on it alternately. The construction of the drum varies according to the requirements; they are sometimes entirely of iron, but more generally lagged with wood, as shown in Fig. 43, being provided with a rim for the brake band to work in. The sizes of the drums vary according to requirements, but it is not advisable to have them less than four feet in diameter for wire rope. For the convenience of the operator in watching the cars, the brake levers are preferably placed near the top of the slope. Instead of one large drum, two smaller ones keyed to the same shaft (Fig. 44) may be used. In either case one rope leads from the top and the other from the underside of the drum. Where this is an objectionable feature, the arrangement shown in Fig. 45 may be used, which allows of both ropes leading from the top. The two drums in this case are on different shafts, connected by a pair of spur gears, and consequently revolve in opposite directions. In using double drums it is necessary to provide for the unequal stretching of the two ropes, and this is very easily effected by the special arrangement of spiders which we have designed for this purpose, shown in Fig. 46. The end spiders of the drums are secured by means of pins, p, p, to a central spider, s, keyed to the shaft, and by changing the relative positions of

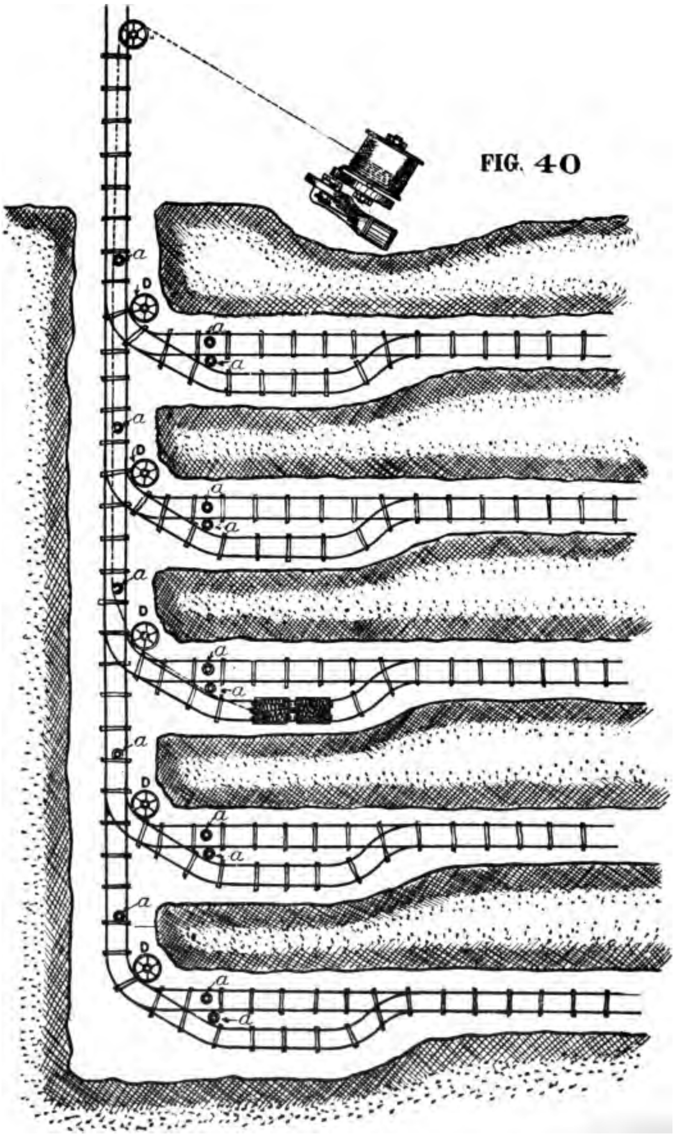


FIG. 40

these spiders any desired adjustment may be made. This style of drum is also applicable on engine planes where it is desirable to work from different levels.

There are several plans of laying the tracks for gravity planes. Fig. 49 represents a regular double-track line on which the loaded cars descending on one track pull up the empty cars on the other. This is, of course, the safest, though most expensive arrangement. A cheaper arrangement, and one which answers the purpose quite as well, is shown in Fig. 50, and consists of a three-rail track, having a "parting" or double track at the middle of the incline, long enough to allow the descending and ascending cars to pass each other. A still cheaper arrangement is that shown in Fig. 51. This line has three rails from the top of the slope only to the parting, and a single track below that; a self-acting switch at the lower end of the parting guides the cars alternately from one to the other of the upper tracks. Fig. 53 shows a common arrangement of this switch, and, as shown in the cut, an empty car going up will take the track, *s*, and the loaded car coming down the track, *m*, will shift the timbers to the positions indicated by the dotted lines. At the next trip the empty car will run on the track, *m*, and the loaded car, this time descending on the track, *s*, will shift the timbers again to their original position, the same play being repeated at every alternate trip. This switch is effective, and accidents with it are of rare occurrence. In cases where difficulties occur to prevent obtaining sufficient width to permit the passing of two cars, automatic gravity planes, worked with a counterweight and generally known as "bob planes," can be used; such an arrangement is illustrated in Figs. 54 and 55, and consists of a double track, one inside the other; the outer for the mine cars, and the inner, of lighter rails, for the balance car (Fig. 55). This is built in the shape of a shallow iron box, on wheels, heavy enough to pull an empty car up the plane, and light enough to be raised by a descending loaded car. The wire rope is secured to an angular bar behind the balance car, which drops, in case of an accident to the rope, and arrests the car. The head drum may be a grip-wheel, or what is better and cheaper, an elliptic-grooved sheave, around which the rope makes several laps, similar to that described in connection with gravity hoists (Fig. 8).

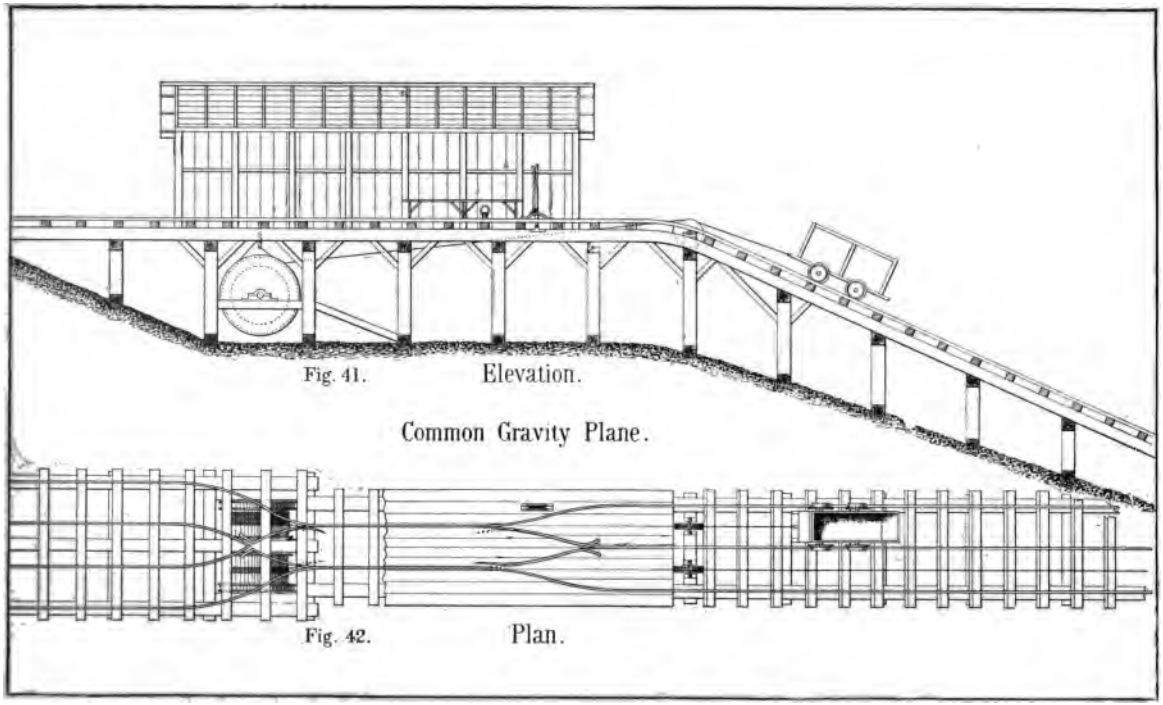


Fig. 41. Elevation.

Common Gravity Plane.

Fig. 42. Plan.

Fig. 48 represents a type of switch commonly used at the head of gravity planes, and consists of three pivoted tongues—*A*, *D* and *E*—which govern, according to their position, the disposition of the cars. The tongue *A* has a spring or weight attached to it which always keeps it closed. With the tongues arranged as shown, a loaded car coming from the track *M* opens the switch *A* and passes to the track *Q*. The switch *A* closes immediately after the car passes it. The empty car ascending by the track *P* opens the switch *E* and passes to the track *N*. The next loaded car from the track *M* will pass to *P*, the empty car from the track *Q* passing to *N*. The loaded cars thus descend alternately by the tracks *P* and *Q*, and the empty cars always pass to *N*.

In gravity planes where the grades are very steep and the duty great, requiring heavy ropes, large drums and powerful brakes, the arrangement illustrated in Fig. 56 is to be recommended, which represents the head gear of the gravity plane at Whitwell, Tenn. There are two horizontal drums—Figs. 57 and 58—seven feet in diameter, ten feet between centers, grooved for four laps of the rope, which is $1\frac{1}{2}''$ diam. Lang-lay. The rope passes over a couple of leading sheaves, seven feet in diameter, at the head of the incline. The brakes are operated by means of a hand-wheel, *h*, attached to the upper end of a vertical rod, *r*, which communicates motion to a horizontal rod, *R*, through a pinion and gear-wheel at the lower end. The rod, *R*, is threaded and works in a fixed sleeve or nut, the gear-wheel working on a feather. This rod connects with the levers, *l*, *l*, which work the brake bands. The plane is about a mile in length, and has a fall of about 1,200 feet. It starts from the top with a fall of 46 feet in 100, running on to a lighter grade at the middle, and then rounding a knuckle to a steeper grade at the lower end. Two cars, holding 6 tons of coal each, are lowered at a trip, the combined weight of the coal and cars being about 18 tons. The capacity of the plane is 100 tons per hour. The track rollers are of iron, 9″ diameter, and spaced from 25 to 30 feet apart. The incline develops so much power that the brakes at the start were found inadequate for the work required of them, and it became necessary to assist or relieve them in some way, which was done by adding a fan-governor, shown in our illustration. This fan is located above the "check-house," and consists of four wooden wings 36″ x 20″ on a

Fig. 46. Compensating Spider.

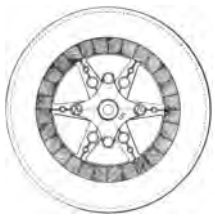


Fig. 48. Automatic Terminal Switch

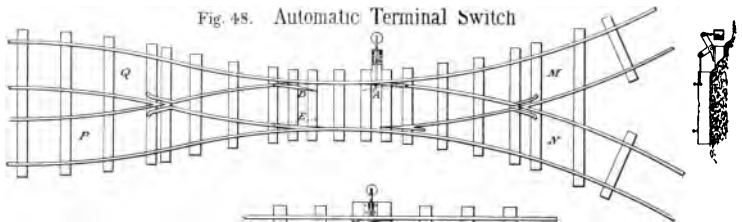
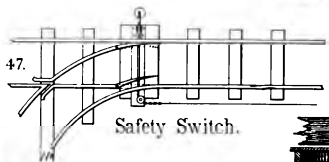


Fig. 47.



Safety Switch.

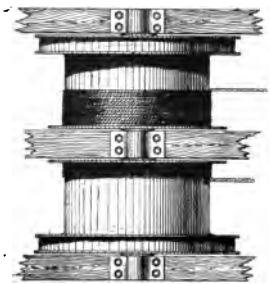


Fig. 44.

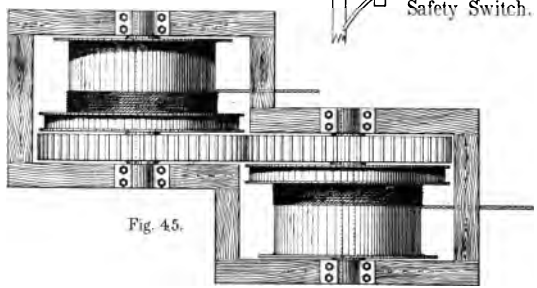


Fig. 45.

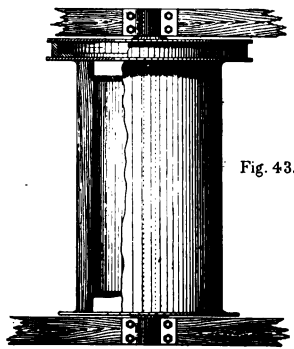


Fig. 43.

Various Styles of Head Drums.

4" shaft, which extends down through the roof of the check-house, and is driven from the main shaft of the back drum. Even with this governor the work on the brakes is still excessive, and the wooden blocks burn out rapidly. A similar gravity plane may be seen at Whiteside, Tenn., but the duty is not nearly as great, and no fan-governor is used.

A style of gravity plane sometimes used is illustrated in Figs. 59 and 60. It consists of a platform car on which the mine cars are carried two at a time. This platform car is attached to a rope which makes a half lap on a brake sheave at the head of the incline, from which it leads to a sheave on a balance car, around which it makes a half lap, and extends up the slope to an anchorage near the check-house. The balance car, commonly known as the "dummy," travels on a separate track parallel with the main track, the movement being one-half that of the incline car on the main track. The dummy is weighted just sufficiently to lift the incline car, supporting the two empty mine cars on their return to the workings. This style of plane is peculiarly adapted to mines that are worked in terraces, or on a series of "headings," as they are termed, at different levels along the side of a hill. Wooden track rollers are generally used, with a few iron ones interspersed where the wear is heavy. In laying out these planes allowance must be made for the variation in the weight of the ropes on the two tracks. This adjustment may be effected in the profiles of either the main or dummy tracks, or partially in both. It is usually more convenient to make it in the dummy track, as this is but half the length of the other, and independent of the location of the headings. In effecting a landing at any heading, the incline car is brought to a stop or a slow speed, within a few feet of it, by the brakeman on the car, who works the brakes gently, till the rails at the heading abut nicely with those on the car, when the car is stopped. The brakeman at the head of the incline then applies the brake to the head sheave; the empty mine cars are run off and replaced by loaded ones. The main objection to this system is the loss of time in making each landing, and the close adjustment of balance weights required to permit of this being done by the brakeman on the car. This difficulty has been avoided by arranging to dump the mine cars, from tipples at each heading, into a

Fig. 52.

Fig. 51.

Fig. 50.

Fig. 49.

Various Arrangements of Tracks

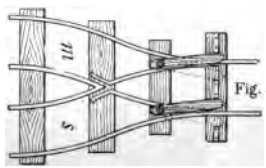


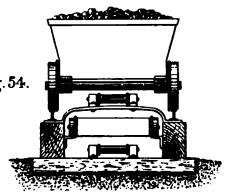
Fig. 53.

Automatic Switch.

Fig. 55.

Bob Plane. Balance Car.

Fig. 54.



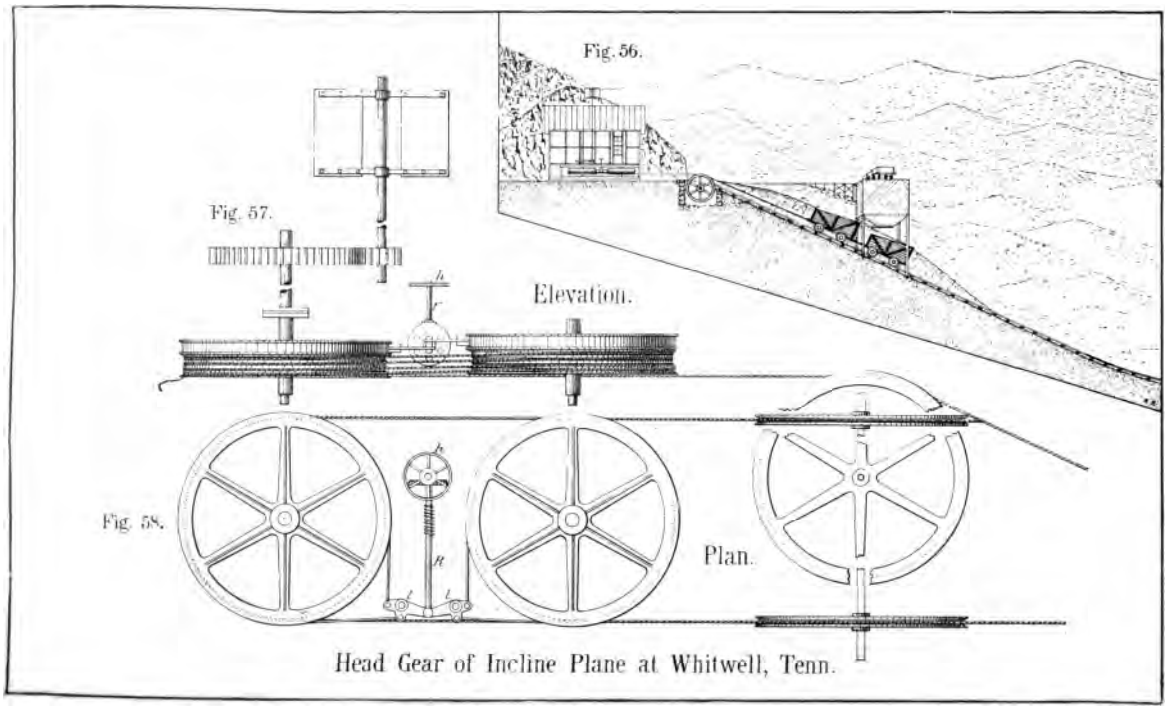
Bob Plane.
End View of Car.

box car, or skip on the incline. In the best-constructed planes of this class, the tracks at the various headings are so arranged that the transferring of the cars to and from the main incline is done entirely by gravity, either by self-acting slopes, or more frequently by taking off the empties at a point above the workings, and taking on the loaded cars at a point below, so that there is a fall, in either case, sufficient to operate by gravity. The main incline is operated by the brakeman at the check-house, an indicator being provided to mark the position of the car on the incline. This method does not require as delicate an adjustment of the balance weight as when the stopping is governed by the brakeman on the car, and landings are effected with regularity and precision.

Incline cars for gravity planes are sometimes constructed to dump automatically, as shown in Fig. 61. The car is fitted with a pair of wheels in front which have a wider tread than those in the rear. These run on to a short section of track at the foot of the plane, the rails of which are level, or nearly so, and are wide enough apart for the back wheels to clear, the latter running on to the steep end of the main track, and discharging the contents from the rear end of the car, as shown. An incline car is used at the Gilreath Mines, Ala., shown in Fig. 62, which discharges from the front, the door being secured by an ingenious latch, which opens automatically on reaching the foot of the incline. The construction of this latch is shown in Fig. 63. The limit of grade at which an inclined plane ceases to operate automatically is difficult to fix arbitrarily, as the conditions of each case vary considerably. No rule can be given for determining the least angle of inclination, as this varies with the length of the plane, the weight and construction of the cars, and road-bed. For planes up to 500 feet in length, the minimum grade may be assumed at about 5 per cent. For longer planes, from 500 to 2,000 feet, it varies from 5 to 10 per cent., being greater in proportion to the length of the line and less in proportion to the load.

The profile of the plane should be concave, if possible, with the steepest inclination at the top.

Very frequently two or more slopes are operated by a system of inclined planes, which may all dip the same way or in different direc-



Head Gear of Incline Plane at Whitwell, Tenn.

tions, and may be either self-acting, or require power, according to the grades. The best method of working in any case will depend upon the special requirements of the location.

The stresses upon the ropes of inclined planes may be determined from the subjoined table, but it should be borne in mind that while the table is based upon an allowance of 40 pounds per ton for rolling friction, there will be an additional stress due to the weight of the rope, proportional to the length of the plane :

STRESS IN HOISTING ROPES ON INCLINED PLANES OF VARIOUS DEGREES.

Rise per 100 ft. horizontal.	Angle of inclination.	Stress in pounds per ton of 2,000 pounds.	Rise per 100 ft. horizontal.	Angle of inclination.	Stress in pounds per ton of 2,000 pounds.
Ft.			Ft.		
5	2° 52′	140	105	46° 24′	1484
10	5° 43′	240	110	47° 44′	1516
15	8° 32′	336	115	49° 00′	1535
20	11° 10′	432	120	50° 12′	1573
25	14° 03′	527	125	51° 21′	1597
30	16° 42′	613	130	52° 26′	1620
35	19° 18′	700	135	53° 29′	1642
40	21° 49′	782	140	54° 28′	1663
45	24° 14′	860	145	55° 25′	1682
50	26° 34′	933	150	56° 19′	1699
55	28° 49′	1003	155	57° 11′	1715
60	30° 58′	1067	160	58° 00′	1730
65	33° 02′	1128	165	58° 47′	1744
70	35° 00′	1185	170	59° 33′	1758
75	36° 53′	1238	175	60° 16′	1771
80	38° 40′	1287	180	60° 57′	1782
85	40° 22′	1332	185	61° 37′	1794
90	42° 00′	1375	190	62° 15′	1804
95	43° 32′	1415	195	62° 52′	1813
100	45° 00′	1450	200	63° 27′	1822

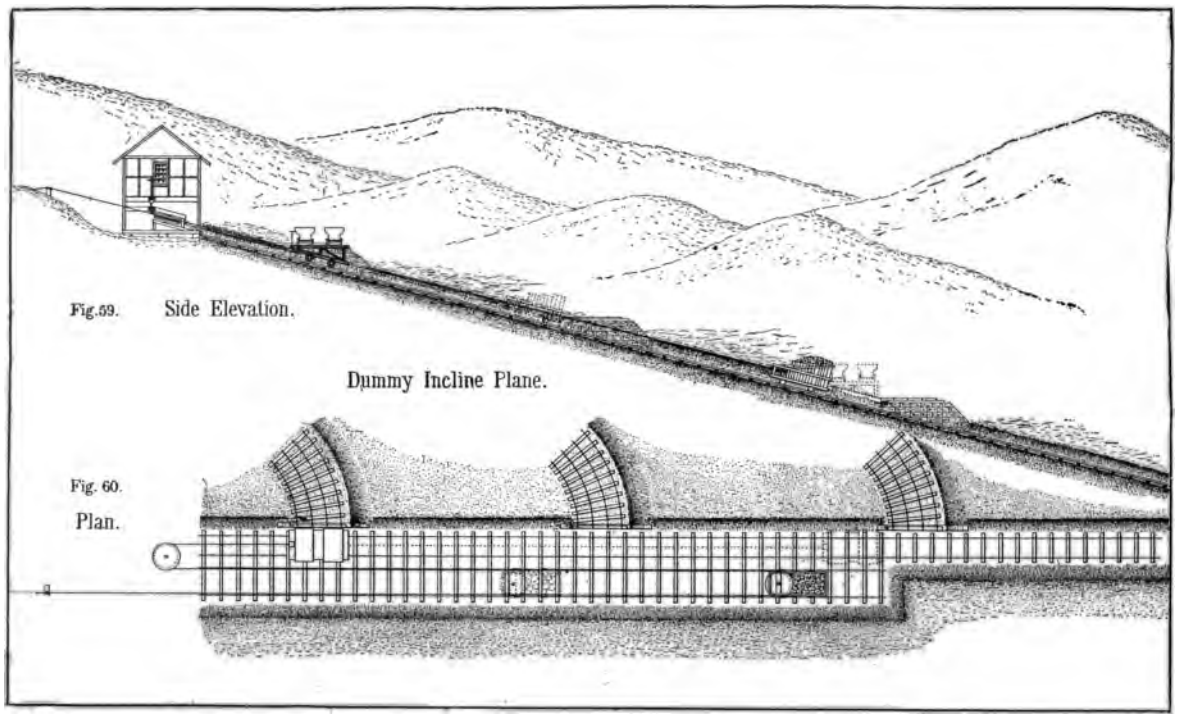


Fig.59. Side Elevation.

Dummy Incline Plane.

Fig. 60.

Plan.

HAULAGE PLANTS.

Where grades are so slight that gravity cannot be utilized as a motive power, a continuous system of wire rope haulage is commonly applied. There are two general arrangements of this kind, known respectively as the "tail rope" and the "endless rope" systems.

TAIL ROPE SYSTEM.

The tail rope system is one by which the haulage of the loaded cars is accomplished with one rope, while the empties are drawn back by a separate light rope known as the tail rope. The two drums upon which these ropes coil may be located at the opposite ends of the line and driven by independent engines, as in Fig. 64, or preferably located at the mine entrance, and driven from the same engine, as in Fig. 65. The latter arrangement requires more tail rope, but saves the expense of an extra engineer, besides permitting the erection of the engine outside the mine. At the end of the main line and of each branch there is a sheave from 4 to 5 feet in diameter, called the "tail sheave," around which the tail rope passes.

The drums are generally driven by friction or clutch connections, from the engine shaft, so that each may be alternately driven, or left to uncoil loose, as desired. These drums are provided with brakes wherever the grades make it necessary. Fig. 66 illustrates an improved type of the tail rope engine as now generally used. Two independent lines are often operated by one engine, in which case four drums, as shown in Fig. 67, are arranged to be worked by one man.

In all cases the size of the ropes should be proportioned to the strains they have to bear; as a rule, rope of 7 wires to the strand is to be recommended for the main rope, and rope of 19 wires to the strand for the tail rope, since the main rope is subjected to the greatest surface wear and the tail rope to the greatest amount of bending. The tail rope is conducted to the tail sheave over rollers, usually of iron, supported at an elevation of 3 or 4 feet above the track on upright timbers along the side of the gangway, as shown in Fig. 68. The track rollers are generally of gumwood, although iron rollers are frequently used to advantage, especially at points where the wear is heavy.

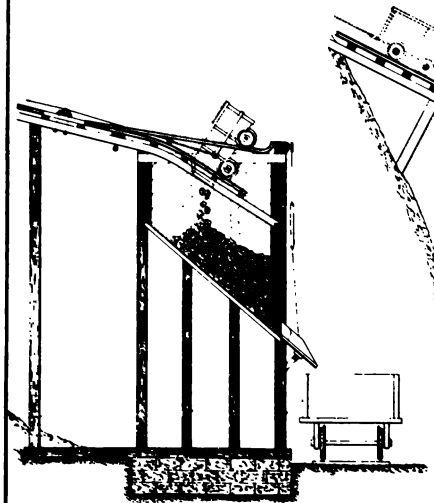


Fig. 61.

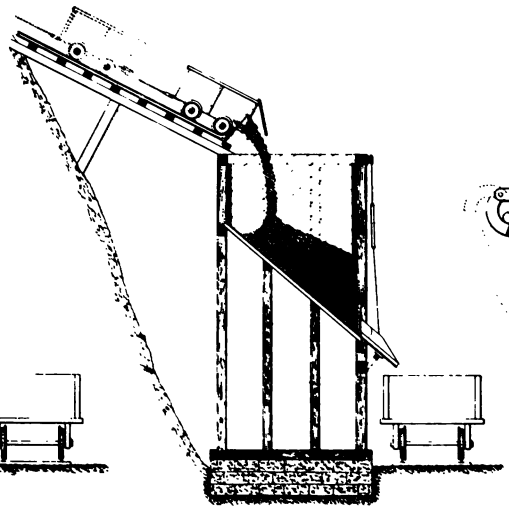


Fig. 62.

Self-Dumping Incline Cars.

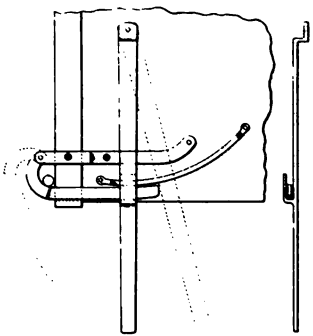


Fig. 63.

Automatic Latch.

Curves may be made at any angle and of comparatively small radii, but where the radius is less than sixty feet, the trips should be taken around the curve at a moderate speed. The ordinary speed at which the ropes may be run varies from 8 to 12 miles an hour. The number of cars composing a trip depends largely on the grades, and varies usually from 25 to 50. In some mines, however, as many as a hundred cars are handled at one haul.

Couplings are provided in the tail rope, by means of which the proper attachments may be made with the various branch ropes, which simply complete the tail rope line on their respective entries. In taking a trip into any side or cross entry, therefore, it is understood the branch ropes on the other side entries, as well as that portion of the tail rope on the main gangway which is disconnected for the time being, simply lie idle. There are three methods of attaching the branch ropes, as illustrated in Figs. 69, 70 and 71. In the first two the change is effected when the trip reaches the junction of the main and branch ways, and in the last when the trip is at the entrance or shaft.

In the first arrangement, Fig. 69, a sheave is fixed near the roof or under the track, around which one end of the branch rope passes. In going in, the rope end *C* replaces *D*, on the front end of the train, and the end *E* replaces *F* in the tail rope. In the arrangement illustrated in Fig. 70, the tail rope always remains entire; the end *A* replaces *B*, and the latter end, being pulled in a little further, is attached to *N*.

In changing the ropes by the method illustrated in Fig 71, a different course entirely is pursued. The branch ends are changed by a boy while the trips are being made up at the entrance or shaft, the couplings in the tail rope being set to come opposite the loose ends of the branch rope, as shown, when the ends *X*, *X* are replaced by *Y*, *Y*. This plan is much more expeditious than either of the others, since no time is lost in changing the ropes, as they are generally ready at the branch before the trip at the entrance is ready to be taken in, and the change is made when there is no strain on the ropes. In the first two methods there is a loss of time, not only by reason of the additional stoppages at the branch, but also due to the fact that the trains usually arrive at the branch with the ropes under considerable tension. This makes it

FIG. 64.

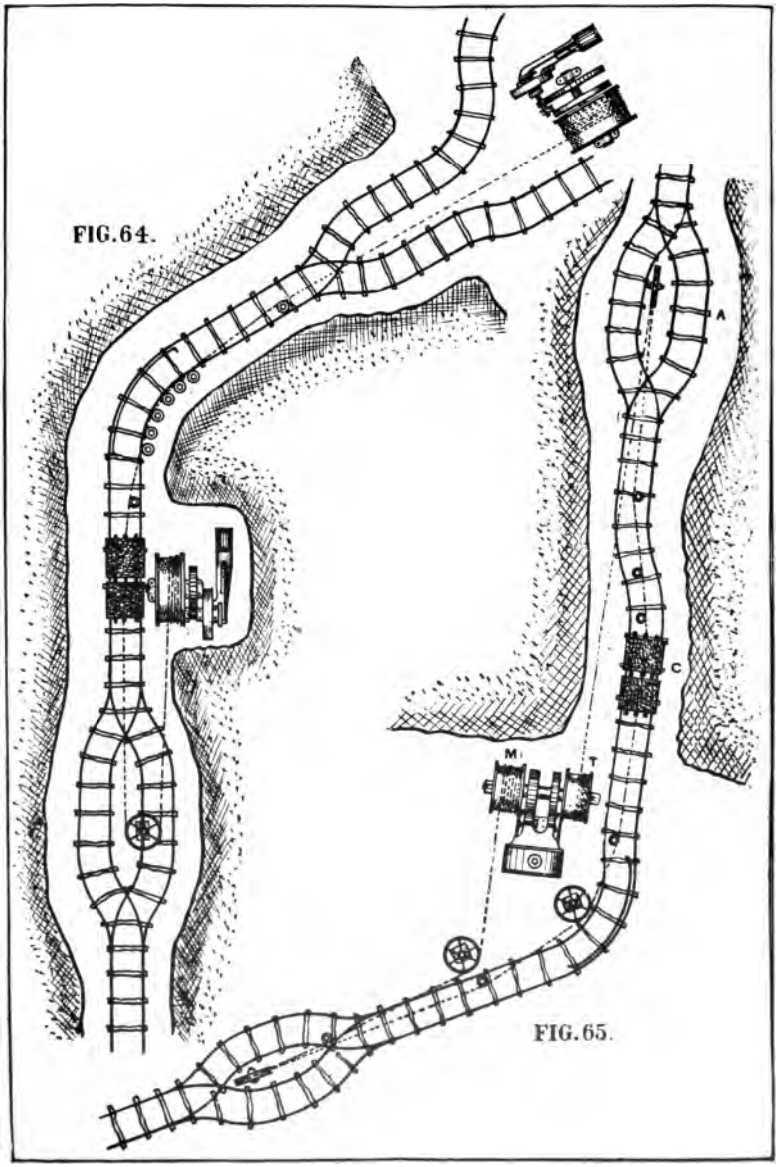


FIG. 65.

necessary very often, in changing the ropes, to use a winch to bring the ends together. A wooden clamp, fixed at one side of the entry, is sometimes used to hold the tail rope while the branch rope is being attached, the clamp being applied before the tail rope is released, which prevents it from springing back.

To uncouple the ropes while under strain it is necessary to use peculiar hooks, known as "knock-off" links. There are various styles of these, the most common of which are illustrated in Figs. 78 to 83. Their operation will be readily understood by a glance at the illustrations. Fig. 83 represents a self-acting knock-off link. When the train arrives at the point where the rope should be released, a bar of iron fixed at the proper point comes in contact with the bell-crank lever lifting the chains connected with the knock-off link, and releasing the rope. These links are usually applied both to the main and tail ropes. Fig. 75 represents a common style of tail rope coupling, which is simply a hook and loop socket connected by a link. The link may be dispensed with by using two hook sockets, as shown in Fig. 76, that go together like the hooks of a bell-cord. This is safer where the tail rope is likely to become slack at times. Fig. 77 represents another style of connection, where two strap sockets, with a single link in each, are connected by a flat steel hook attached to one of the links as shown. The opposite link has a notch in it through which the hook is passed, the opening being just wide enough to slip over the link at this point.

Stations on either side of the main or branch lines are usually worked by an arrangement of tracks, as shown in Fig. 72. The ropes are knocked off the empty train in going in at the points *A*, *A*, opposite to which is the train of loaded cars ready to go out. A gentle fall in the track causes the empty train to run forward over the switch *S*, on to the siding *B*.

In mines which have been opened by vertical shafts or steep inclines, the tail rope system of haulage operates only to bring the cars to the foot of the shaft or incline, whence they are hoisted to the surface by methods already described. Under these circumstances the tail rope engine may be placed either at the foot of the shaft or at the surface, as may be deemed most desirable. The latter position is preferable, notwithstanding the extra length of ropes required, owing to the advantage of having the engine out of the mine.

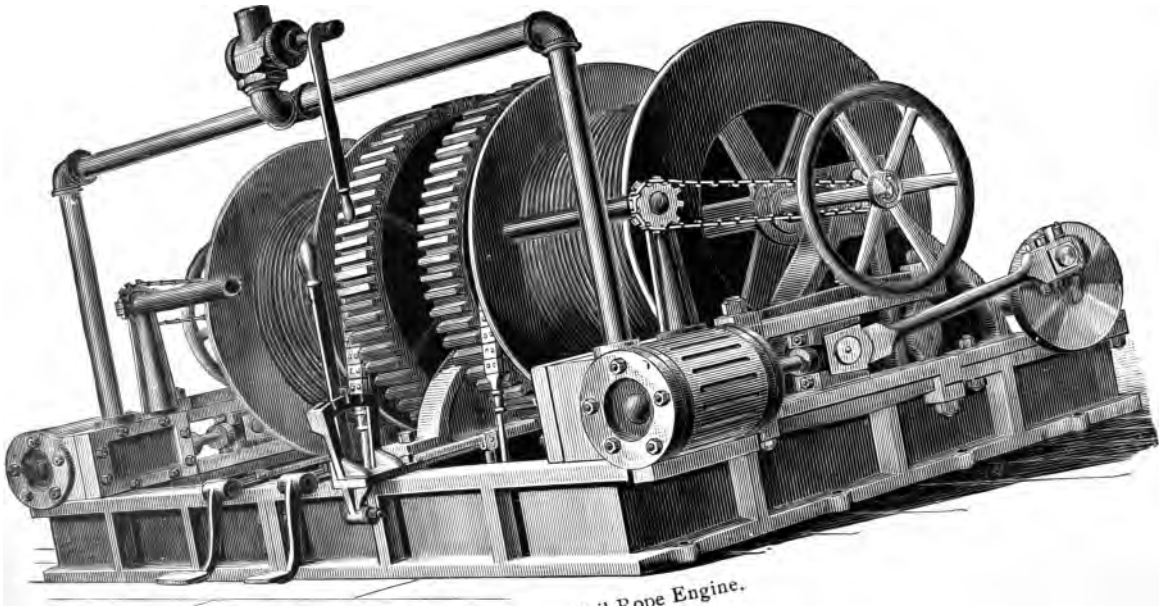


Fig. 66.—Tail-Rope Engine.

If the slope into the mine is an easy one, the trips may be hauled directly out, by providing an engine of sufficient power, and if at the same time the grade is steep enough for the empty trips to descend by gravity, the tail rope connections may be made at the foot of the slope.

Where the slope from the mine entrance to the tipple is in favor of the loaded trips, these may be lowered directly by means of the tail rope, the main rope being knocked off as soon as the trip comes out of the mine. In fact, a variety of conditions may occur to modify the character of the line and method of operating; the grades being a most important feature in this consideration. In laying out and estimating on any line, therefore, the importance of having an accurate profile to work to is manifest.

ENDLESS ROPE SYSTEM.

The endless rope system, as its name implies, is based on the operation of an endless rope. Usually this is run continuously in one direction, the engine being fitted with a fly wheel and governor, and requiring but little attention. The cars are attached at any point, by means of clutches or grips, of which a variety of styles have been devised.

Sometimes, however, the rope is operated in both directions, in which case a reversing engine is required. This is practically a modification of the tail rope system, as the trips are handled in the same manner, excepting that the attachments are made to an endless rope. These attachments usually consist of links socketed in the rope, which are not as ojectionable in this case as they would be in the other, since they do not have to pass around the engine drums.

The engine drums, two in number, are from 4 to 8 feet in diameter, placed tandem on horizontal shafts, and usually mounted on one bed-plate with the engine, as shown in Fig. 84. The rope is lapped a sufficient number of times about these drums to prevent slipping, the drums being grooved accordingly. The engine is geared to the back drum, while the forward drum, which is set at a slight inclination, in order that the rope will lead properly from one groove to the other, runs free in its bearings. The latter drum, in the engine we have illustrated, consists of a set of independent sheaves mounted in such a way

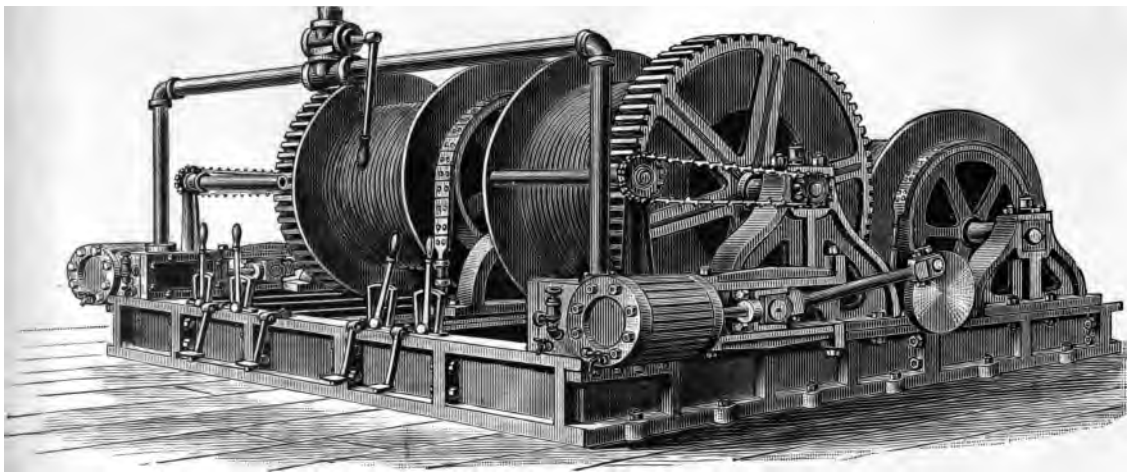


FIG. 67.—Tail-Rope Engine, with Four Drums.

as to compensate for irregularities in the wear of the grooves, which in ordinary drums has a tendency to stretch the rope unduly. The bearings of this drum are on slides actuated by long bolts, and a single lever working a double ratchet to provide for taking up the stretch of the rope. These engines are made in a variety of sizes.

In all lines of this class a certain amount of tension in the rope is necessary. This should be so proportioned that the driving can be effected with the minimum number of laps on the drums, while the rope still remains slack enough to enable the cars to round the corners without too much side pressure. The tension may be applied at either end, but preferably at the end where the line is driven. The ordinary arrangement is to mount the tail sheave on a carriage, as illustrated in Fig. 100. A chain attached to the carriage passes over a small wheel and supports the tension weights.

The illustration on page 122 represents the arrangement of an endless rope line at the East Fork Mine of the Tennessee Coal, Iron and Railroad Company, at Tracy City, Tenn. The line traverses a main tunnel through the mountain, 6,000 feet long, to No. 10 mine, and a branch tunnel, 1,800 feet long, to No. 11 mine, making in all 7,800 feet, as exhibited in Fig. 86. The loaded track at the entrance is on a one per cent. grade, descending to the tipple, while the empty track, after passing over a slight knuckle, is on a one per cent. grade descending from the tipple for a distance of 250 feet, then level for about 50 feet, then on a three per cent. rising grade, until it reaches the level of the loaded track. The loaded cars from No. 10 mine and the empties to No. 11 mine run by gravity across the places where the rope is lacking at the junction of the main and branch lines. Figs. 89a and 89b show the style of grooved curve sheaves and track rollers used, which were designed by Mr. Chas. E. Bowron, the engineer at the Tracy City Mines.

The rope is $\frac{3}{4}''$ diameter steel, 7-wire, Lang-lay, and travels at a speed of 4 miles an hour. The rope is greased continuously with a mixture of coal tar, car oil and axle grease. The tension sheave near the entrance is 5 feet diameter, and is mounted on a carriage, actuated by weights suspended in a gallows frame. The sheave is slightly inclined to the vertical in order that the rope may lead on and off properly. The tail sheaves are 6 feet diameter, and mounted on " take-

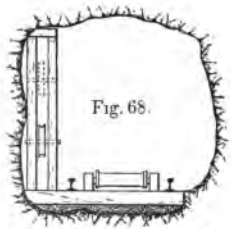


Fig. 68.

Track and Tail-Rope Rollers.

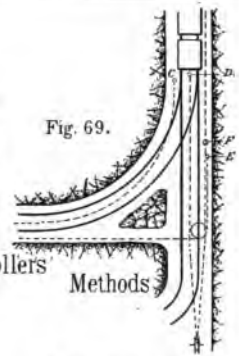


Fig. 69.

Methods

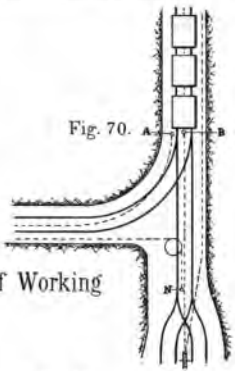


Fig. 70.

of Working

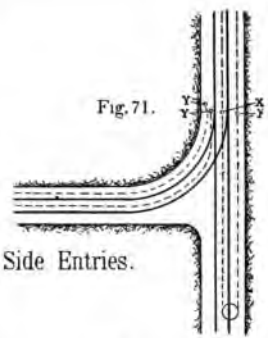


Fig. 71.

Side Entries.

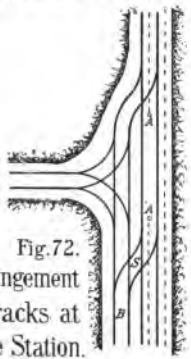


Fig. 72.

Arrangement of Tracks at Side Station.

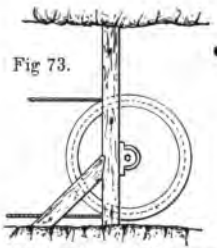


Fig 73.

Vertical Tail Sheave

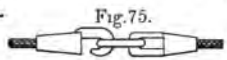


Fig. 75.

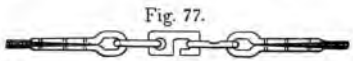


Fig. 77.

Various Styles of Tail-Rope Couplings.

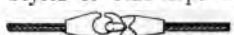


Fig. 76.

Horizontal Tail Sheave.

Fig. 74.

up" slides. The engine is located directly in front of the mine entrance ; it has double cylinders, 16 x 20, and is geared 1:4 to the back drum. This drum is 6 feet diameter, and the forward drum 5 feet diameter. The loaded rope leads direct to the upper side of the back drum, makes three half laps about this and the forward drum, one half lap next about the tension sheave, one half lap finally about a sheave which revolves freely on the driving drum shaft, and leads out under the tension carriage around some small guide sheaves to the left. Twenty cars make up a trip, holding each about 1,500 lbs. of coal, and weighing, empty, about 750 lbs. The road is comparatively level, the steepest grade being less than 2½ per cent., and the maximum daily capacity of the line is 1,200 tons. The average cost of hauling for the three years, during which the output amounted to some 580,000 tons of coal, was 7.14 cents per ton, which includes, besides the rope haulage, the cost of delivery from face of entries at the two mines to the rope terminals by mules, this additional distance varying from a quarter to one mile. The cost of hauling from the rope terminals to the tipple is about 4 cents a ton or 3 cents a ton per mile ; this figure including depreciation of plant, etc.

The manner of attaching the cars to the rope in this system claims special attention, as its successful operation depends largely on the effectiveness of the grips. There have been a variety of these grips and other devices invented for taking hold of the rope. One of the oldest, simplest, and by many mine operators still considered the best, is the grip tongs illustrated in Figs. 90 and 91. They have been used for years in the English collieries. The tongs are attached to the draw bar of the front car by a short chain (Fig. 91), which provides for the necessary lateral motion in going round curves. Fig. 92 illustrates another style of grip, with a fixed lower jaw consisting of a projection at the bottom of the box which contains the mechanism for operating the upper or movable jaw, by means of the handle shown. The box is attached to the draw bar of the front car by a rod, in such a way as to prevent the grip turning over. The grip works very well so long as there is a pull on it, but on down grades, where the cars are likely to run ahead of the rope, it must be taken off. In such cases the trips may frequently be checked by applying brakes to the front car, especially if the descent is in favor of the empty trips. Where this

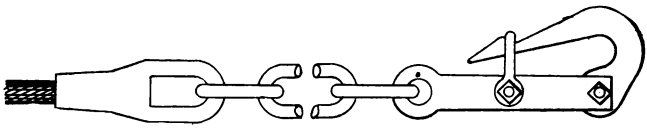


Fig. 78.

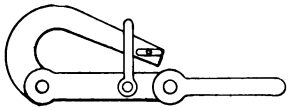
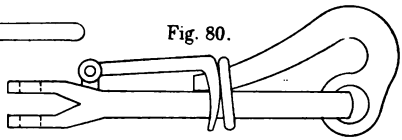


Fig 79.

Fig. 80.



Various Styles of Knock-Off Hooks.

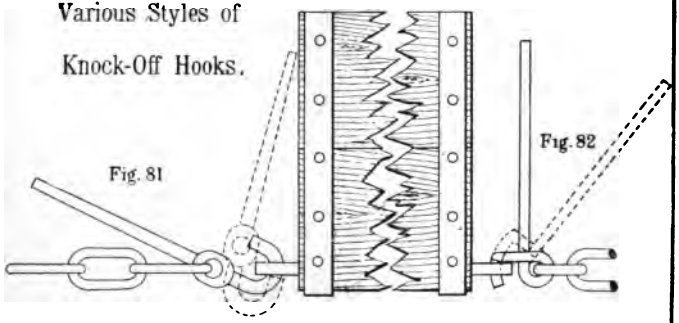


Fig. 81

Fig. 82

Self-Acting Knock-Off Hook

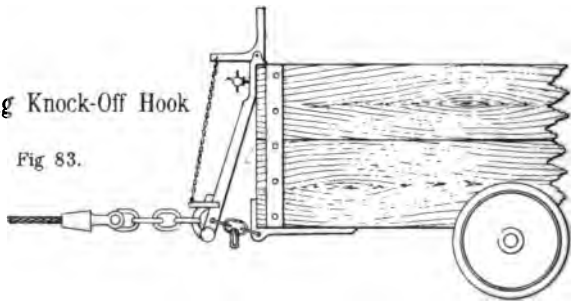


Fig 83.

cannot be done, a grip car must be used, as illustrated in Figs. 93 and 94. The grip is attached to a plate pivoted at the back end of the car, to provide for the necessary lateral motion in going around curves, and avoid the racking that would occur from vibrations of the rope if the grip was rigidly attached. The grips and cars are made in sizes to correspond with the work they have to do.

An endless rope line is also used at Tracy City for charging two double lines of coke ovens, known as the East Fork and Lone Rock batteries, and covering a total length of 3,700 feet, in which there are several bends. Two double discharge larries, each of 10 tons capacity, are employed, one for each battery, which travel upon single tracks between the two lines of ovens, and are attached to the endless moving ropes by means of grips similar to that illustrated in Fig. 92. The rope used is $\frac{5}{8}''$ diameter, 7-wire, Lang-lay, and runs along the center of the tracks back and forth in double lines over iron rollers spaced from 15 to 20 feet apart, similar to those shown in Fig. 89b. The grade on the East Fork battery is $\frac{9}{10}$ per cent. in favor of the loaded larry, and on the Lone Rock battery it is level. An engine of 10 horse power operates the plant.

The endless rope system may be used on either single or double-track lines. With single tracks, however, turnouts must be provided for the trips to pass, and on this account the double track is to be preferred.

Connections are made with side entries, as illustrated in Figs. 95 and 96. The rails must be cut out where the rope crosses, in order to allow the grips to pass. Short bars, pivoted at one end of each, are introduced, which are usually opened and closed by the train riders.

Fig. 97 illustrates the automatic rail latch devised by Mr. Tyler Calhoun, and consists of a cast-iron plate, *B*, firmly bolted to the ties, with a groove, *g*, through which the rope runs. The latch, *l*, pivoted at *p*, has a beveled end, abutting with the rail end, which is also beveled to fit. This latch completes the rail line, and is set so that it offers no resistance to the passage of the grips. The latch is provided with a spring, *s*, which closes it after a grip has passed, and therefore requires no attention. On single-track lines two of these are placed end to end, as shown in Fig. 96.

Fig 98 illustrates the arrangement of a turnout in a single-rope line, rail latches such as we have just described being required at each

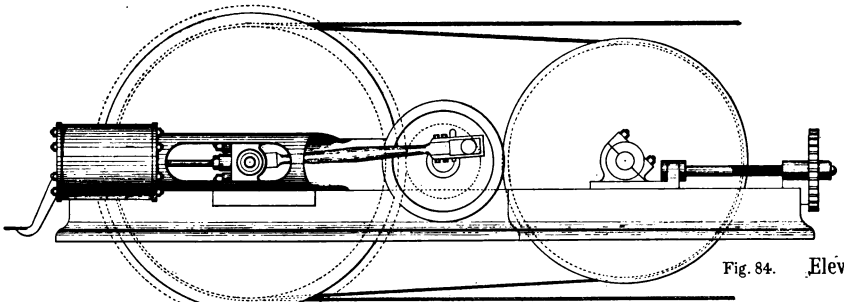


Fig. 84. Elevation.,

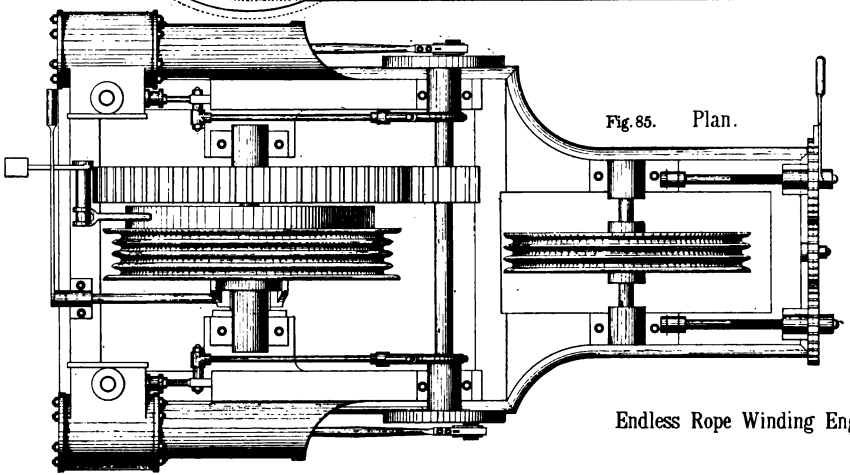


Fig. 85. Plan.

Endless Rope Winding Engine.

of the points marked *B*. Fig. 99 shows the manner of leading the rope around a curve. An arrangement by means of which a side entry may be worked by the rope line is illustrated in Fig. 101. The rope passes around a series of curve rollers between the rails of the ingoing track leading into the branch, and in returning is deflected about a sheave, as shown below the ingoing track on the main entry, and continues on down this entry. The ingoing trains not intended for the branch must be detached at this point.

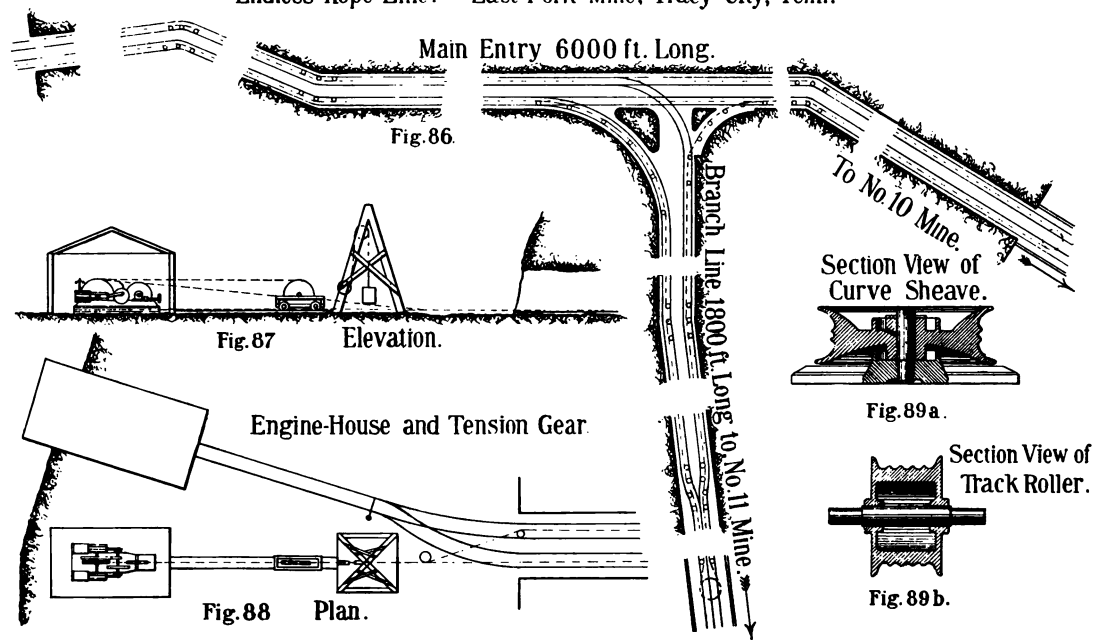
An adaptation of the endless rope system is employed in several English mines, in which the rope, instead of being supported on rollers close to the ground, travels above the cars, the attachments being made in a variety of ways. In some cases the rope simply rests in grips on the cars, and supporting rollers are dispensed with altogether. None of these methods have met with much favor in this country, principally on account of the awkward rope connections and cumbersome arrangements necessary at the curves. Where the dip is all in one direction only a single connection is necessary ; but where the grades are undulating, connections must be made at each end of the trip. There is perhaps one condition of roadway in which this adaptation of the endless rope system might be economically applied, and that is, *when a main gangway without branches has a dip only in one direction.*

The endless rope system is sometimes applied to the operation of inclined planes, where the inclination is comparatively light and duty very heavy. There are a number of planes of this character in the anthracite region of Pennsylvania, among which may be mentioned the planes of the Central Railroad Company of New Jersey, at Ashley, Pa , and the plane of the Philadelphia and Reading Railroad Company, at Mahanoy. Whole trains of loaded cars, as used on the above railroads, are handled on these planes, the raising and lowering being done by means of "barney" cars attached to the ropes, which drop into pits at the lower ends of the planes, out of the way.

At Ashley there are three inclines, one above the other, with a combined length of 13,020 feet, and total vertical elevation of 1,066 feet. Over 24,000 tons have been taken up these planes in 24 hours, the ropes used being of iron $2\frac{1}{2}$ and $2\frac{3}{4}$ inches in diameter.

The Mahanoy plane is 2,466 feet in length, with a vertical elevation of 353 feet, and maximum capacity of 1,000 cars in 24 hours, or

Endless Rope Line. East Fork Mine, Tracy City, Tenn.



about 25,000 tons. The rope used is $2\frac{1}{4}$ inches in diameter, but it is proposed to replace this with a $2\frac{1}{2}$-inch rope.

The amount of artificial tension to be applied in an endless rope to prevent slipping on the driving drum, depends on the character of the drum, the condition of the rope and number of laps which it makes. If T and S represent respectively the tensions in the taut and slack lines of the rope ; W, the necessary weight to be applied to the tail sheave ; R, the resistance of the cars and rope, allowing for friction ; n, the number of half laps of the rope on the driving drum ; and f, the co-efficient of friction, the following relations must exist to prevent slipping :

$$T = Se^{fn\pi},\ W = T + S, \text{ and } R = T - S;$$

from which we obtain—

$$W = \frac{e^{fn\pi} + 1}{e^{fn\pi} - 1} R,$$

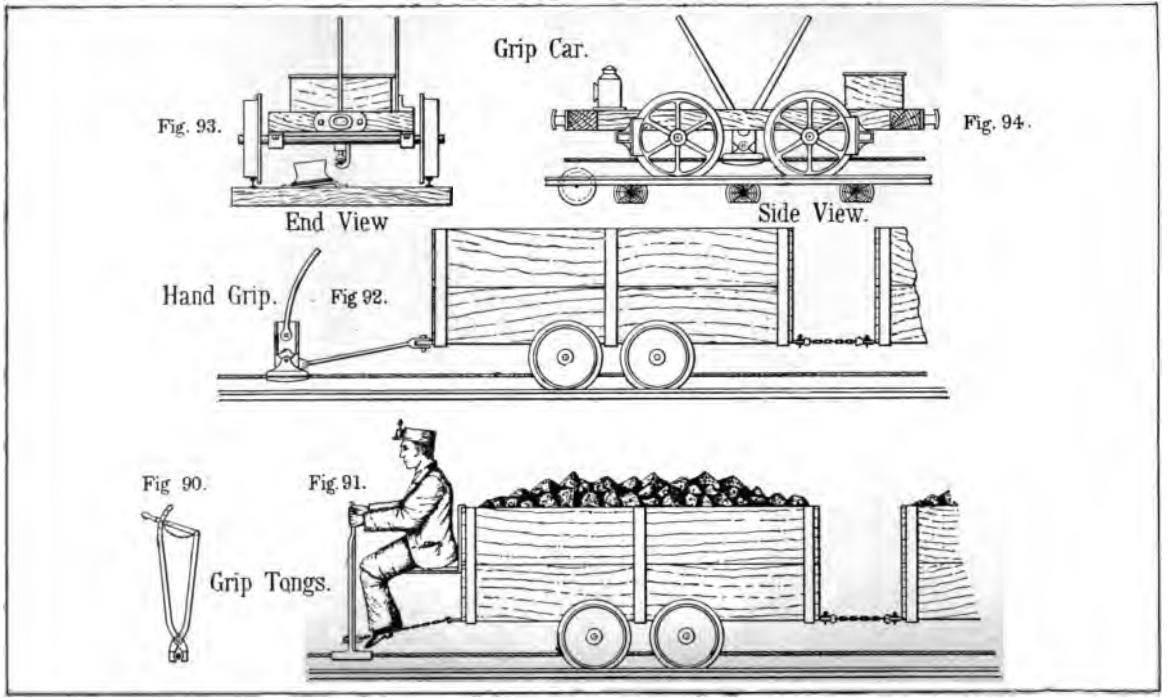
in which e represents the base of the Naperian system of logarithms.

The following are some of the values of f:

Dry	rope on a grooved iron drum,	.120
Wet	" " " " "	.085
Greasy	" " " " "	.070
Dry	" " wood filled sheaves,	.235
Wet	" " " "	.170
Greasy	" " " "	.140
Dry	" " rubber and leather filling,	.495
Wet	" " " " "	.400
Greasy	" " " " " "	.205

The values of the co-efficient $\frac{e^{fn\pi} + 1}{e^{fn\pi} - 1}$, corresponding to the above values of f, for one up to six half laps of the rope on the driving drum or sheaves, are as follows:

f	n = NUMBER OF HALF LAPS ON DRIVING-WHEEL.					
	1	2	3	4	5	6
.070	9.130	4.623	3.141	2.418	1.999	1.729
.085	7.536	3 833	2.629	2.047	1 714	1 505
.120	5.345	2.777	1.953	1.570	1.358	1.232
.140	4.623	2 418	1.729	1.416	1.249	1.154
.170	3.833	2.047	1.505	1.268	1.149	1.085
.205	3.212	1.762	1.338	1.165	1.083	1.043
.235	2.831	1.592	1.245	1.110	1.051	1.024
.400	1.795	1.176	1.047	1.013	1.004	1.001
.495	1.538	1.093	1.019	1.004	1.001	.....


Grip Car.
Fig. 93.
Fig. 94.
End View
Side View.
Hand Grip.
Fig 92.
Fig 90.
Fig. 91.
Grip Tongs.

It requires but a glance at these figures to convince one of the importance of keeping the rope dry.

When the rope is at rest, the tension is distributed equally on the two lines of the rope, but when running there will be a difference in the tensions of the taut and slack lines, equal to the resistance, and the values of T and S may be readily computed from the foregoing formulæ.

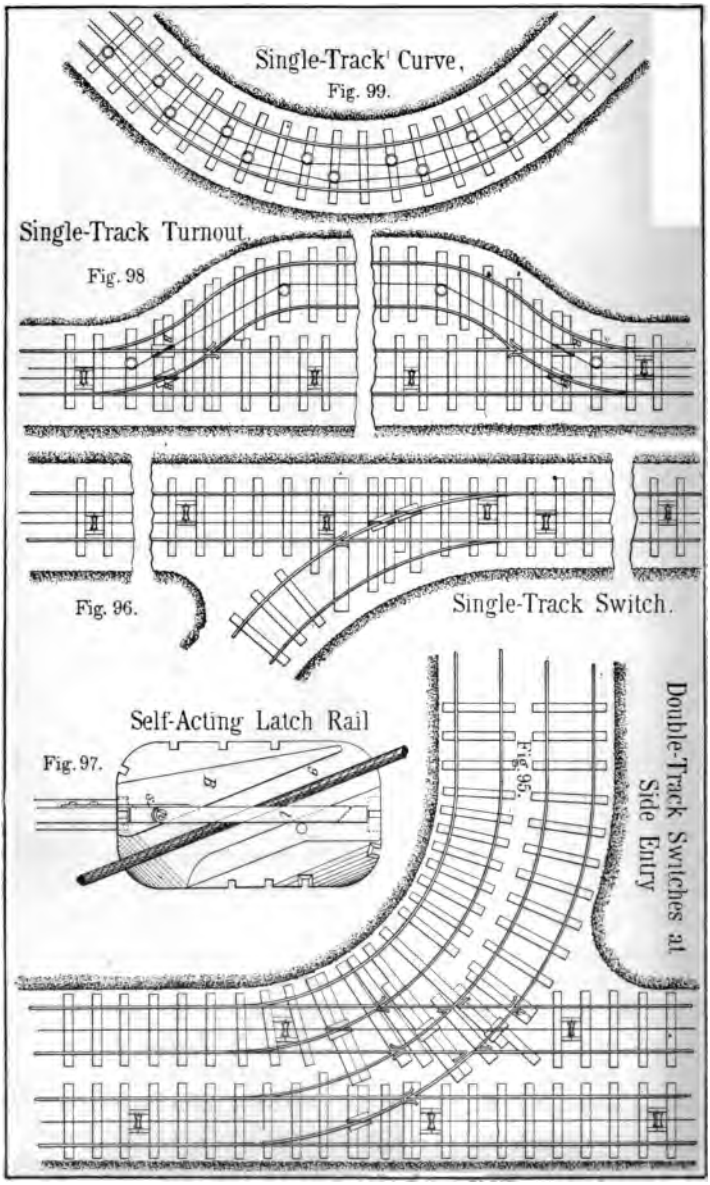
The increase in tension in the endless rope, compared with the main rope of the tail rope system, where the stress in the rope is equal to the resistance, assuming $f = 40$, is as follows :

$n =$	1	2	3	4	5	6
Increase in tension in endless rope, compared with direct stress.	Per cent. 40	Per cent. 9	Per cent. $2\frac{1}{3}$	Per cent. $\frac{2}{3}$	Per cent. $\frac{1}{6}$	Per cent. $\frac{1}{10}$

The above figures will be found useful in determining the proper size of rope. For instance, if the rope makes two half laps on the driving drum, the strength of the rope should be 9 per cent. greater than a main rope in the tail rope system.

COMPARATIVE ADVANTAGES OF THE TAIL ROPE AND ENDLESS ROPE SYSTEMS.

As to which is the better of the two systems of haulage is a matter that depends largely on the local conditions. The tail rope system possesses the decided advantage that crookedness of the line, irregularity of gradient and numerous branches, offer no obstacle to its effective working. To obtain a large output, however, the ropes must be run at high speeds, and as the workings become more extended, an increased number of cars must be handled at each trip. This strains the engine and rope considerably, and the wear and tear therefore is heavier than with the endless rope system, where the rope is run at a moderate speed, and the load more uniformly distributed. The endless rope system requires one-third less rope than the tail rope system, but this advantage is offset by the fact that the rope must be of uniform diameter throughout, and of a size corresponding to the greatest tension under which it will be worked. The power required to operate is


Single-Track Curve,
Fig. 99.
Single-Track Turnout.
Fig. 98
Fig. 96.
Single-Track Switch.
Self-Acting Latch Rail
Fig. 97.
Fig. 95.
Double-Track Switches at Side Entry

less than with the tail rope system, since the rope travels in most cases at less than half the speed, and the friction of an unwinding drum and unloaded rope is not added to the weight of the trips. This fact, in addition to the less quantity of rope required on a line without branches, makes the first cost of the plant somewhat less. The greatest objection to the endless rope system appears to be the difficulty encountered in working branches. These may be operated by independent lines, and conditions may occur where this method of working might be employed to advantage, but in most cases where the length of main line is no drawback, the tail rope system is to be recommended in working lines with branches.

The extensive application of both systems to surface as well as underground lines has demonstrated beyond all question the economy of wire rope haulage, and this economy is very marked where the grades are unfavorable to the load. The cost of wire rope haulage, by either the tail rope or endless rope systems is about the same, and varies, according to the grades, from 2 to 3 cents a ton per mile, which is less than one-third that of mule haulage. The above cost is distributed in percentages about as follows :

System.	Rope.	Maintenance.	Power.	Labor.
Tail rope	15	24	30	31
Endless rope.....	13	26	12	49

The main difference in the above comparison appears in the items of power and labor. While the endless rope system is more economical of power, it is more costly for the labor in handling the cars, and this fact should be taken into consideration in the selection of either system.

Preliminary estimates of cost of construction and expense of operating these lines will be furnished in response to applications, stating length of line, number of curves and their angles, maximum grades in favor or opposed to loads, difference in levels of terminal points, daily output and terminal requirements. Definite estimates can be furnished only after an exact profile of the ground has been made.

Method of Working Endless Rope on Side Entry.

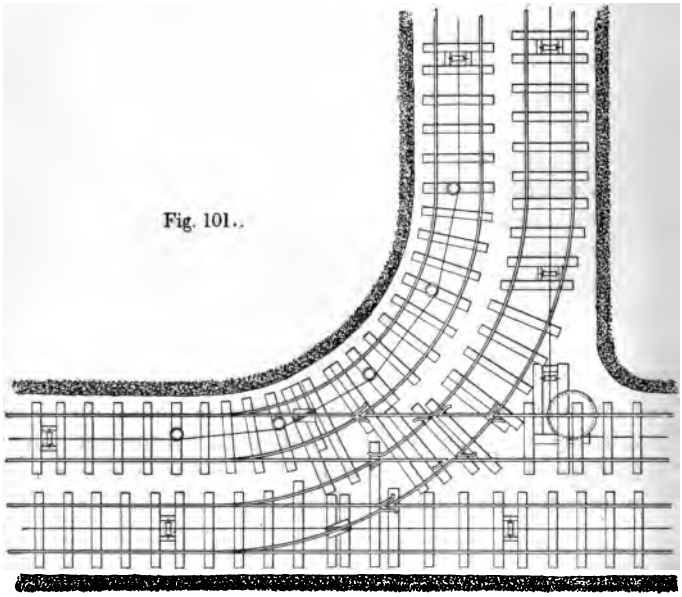


Fig. 101.

Endless Rope Tail Sheave.

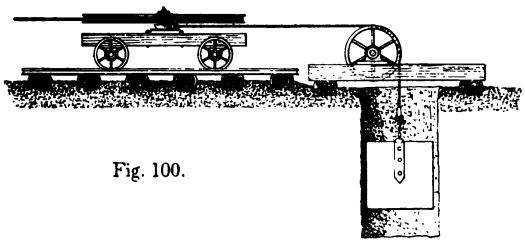


Fig. 100.

Wire Rope and Attachments.

General Remarks.

Ordinary wire rope is composed of six strands, each containing seven, or nineteen, wires, laid up about a hemp or wire strand center, and is commonly known as "seven-wire" or nineteen-wire rope, as the case may be.

Rope made with a hemp center is more pliable than that which has a wire center.

The nineteen-wire rope with hemp center, therefore possessing the greatest flexibility, is to be recommended as a rule for all purposes where running ropes are used ; on the other hand, it is not as well adapted to stand surface wear as the seven-wire rope, and where this is considerable the latter rope is to be preferred, and also where the rope must be run at a high speed, as in the transmission of power.

For special purposes, ropes of twelve and sixteen wires to the strand are made, which are intermediate in flexibility between the seven and nineteen-wire ropes.

We have recently introduced a rope made of eight nineteen-wire strands instead of six, to meet the demand for a more flexible rope than the ordinary hoisting rope and one better adapted to withstand severe bending. This rope, made of plough steel wires, has met with much favor, especially on the Pacific Coast, for logging machines on which comparatively small drums are used.

Hawser ropes are made of six strands, each of which is composed of twelve wires laid about a hemp center.

Tiller ropes, which are the most flexible of all, are composed of six small seven-wire ropes laid about a hemp center.

Endless Rope Haulage, built by THE TRENTON IRON COMPANY, Trenton, New Jersey, for the Trinidad Asphalt Company, La Brea, Trinidad. View of Pitch Lake.

The nineteen-wire rope is as pliable as new hemp rope of the same strength, and can be run over drums and sheaves of the same diameter as the latter. Since wire ropes suffer more from bending strains than from abrasion, it is desirable to use the largest sheaves practicable.

The wear increases with the speed, and it is therefore preferable to increase the load rather than the speed.

Wire rope should not be coiled or uncoiled like hemp rope. When it is wound upon a reel, the wheel should revolve on a spindle while the rope is paid off; when laid up in a coil, not on a reel, roll the coil on the ground, like a wheel, and pay off the rope in that manner, so that there will be no danger of untwisting or "kinking."

To preserve wire rope, cover it thoroughly with *raw linseed oil*, or with a paint made of equal parts of linseed oil and lamp black; when it is subjected to the corrosive action of water it should be saturated with pine tar, applied hot, or with a mixture of coal tar neutralized with slaked lime, using a bushel of fresh slaked lime to a barrel of tar. A number of compounds expressly prepared for covering wire ropes are offered by parties making a specialty of such materials.

Wire ropes are made with a short or long twist, or "lay," according to the purposes for which they are to be used; the former, being more elastic, are preferred where strains are suddenly applied, as on shafts and inclined planes; the latter are preferred on long haulage lines, on account of their stretching less.

We make our own wire, and the best quality of material only is used in our ropes. Our "special" cast-steel wire combines in a high degree ductility and tensile strength, and is subjected to careful tests to insure uniformly good quality.

Under certain special conditions, it is often desirable to obtain considerably greater tensile strength without increasing the diameter and weight of the rope. For this purpose, what is known as "Plough Steel," which will bear a strain of from 100 to 150 tons per square inch, has been found suitable, and is generally used. It should be borne in mind, however, that the increased strength in "Plough Steel" ropes is gained at the sacrifice of some pliability; hence it is vitally necessary, in order to secure the best results, that they should always be provided with drums and sheaves of considerably greater diameter

than those used with ordinary cast-steel ropes of corresponding sizes. Before putting these ropes into use, it will be advisable to confer with us as to their suitability for the proposed service.

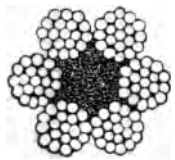
The foregoing grades of rope are sometimes made up of galvanized wires (wires coated with zinc to prevent oxidation) for special purposes, such as suspension bridge cables, etc., where an extra quality of material is required; what is commonly known as "Galvanized Wire Rope," however, such as is used for the standing rigging of ships and for guy ropes, is made of a cheaper material, laid up in six strands of either seven or twelve wires each. For both of these purposes the latter rope has practically superseded hemp rope, since it is more durable, stretches less with changes of weather, and for rigging possesses the further advantage of much less bulk and weight than hemp rope of equal strength.

Flat ropes are made of iron or cast steel wire—usually of the latter. They are composed of a number of round wire ropes (alternately right hand lay and left hand lay) alongside one another, sewed together with annealed iron or steel wire. The component round wire ropes are not made in the same manner as ordinary wire ropes, each being composed of only four strands and having no hemp center. Flat ropes can be made of almost any required width and thickness.

The following tables give the weight, strength, etc., of the different ropes referred to:

PLIABLE HOISTING ROPE.

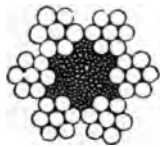
WITH 6 STRANDS OF 19 WIRES EACH.



CAST STEEL.								IRON.							
Trade No.	Diameter, in Inches.	Circumference, in Inches.	Estimated Weight, per Foot, in Pounds.	Breaking Stress in Tons of 2,000 Pounds.	Proper Working Load, in Tons of 2,000 Pounds.	Circumference of Hemp Rope of Equal Strength.	Minimum Diameter of Drum or Sheave, in Feet.	Trade No.	Diameter, in Inches.	Circumference, in Inches.	Estimated Weight, per Foot, in Pounds.	Breaking Stress, in Tons of 2,000 Pounds.	Proper Working Load, in Tons of 2,000 Pounds.	Circumference of Hemp Rope of Equal Strength.	Minimum Diameter of Drum or Sheave, in Feet.
1	2¼	7	8.00	155	31		9	1	2¼	7	8.00	74	15	15½	8
2	2	6¼	6.30	125	25		8	2	2	6¼	6.30	65	13	14½	7
3	1¾	5½	5.25	106	21	15¾	7⅛	3	1¾	5½	5.25	54	11	13	6½
4	1⅝	5	4.10	86	17	14½	6	4	1⅝	5	4.10	44	9	12	5
5	1½	4¾	3.65	77	15	13½	5⅛	5	1½	4¾	3.65	39	8	11½	4¾
5½	1⅜	4¼	3.00	63	12	12¾	5¼	5½	1⅜	4¼	3.00	33	6½	10¾	4½
6	1¾	4	2.50	52	10	11½	5	6	1¼	4	2.50	27	5½	9½	4
7	1⅛	3½	2.00	42	8	10	4½	7	1⅛	3½	2.00	20	4	8	3½
8	1	3⅛	1.58	33	6	9½	4	8	1	3⅛	1.58	16	3	7	3
9	⅞	2¾	1.20	25	5	8	3¾	9	⅞	2¾	1.20	11.50	2⅜	6	2¾
10	¾	2⅜	0.88	18	3½	6½	3⅜	10	¾	2⅜	0.88	8.64	1¾	5	2½
10¼	⅝	2	0.60	14	2⅝	5¾	3	10¼	⅝	2	0.60	5.13	1¼	4½	2
10½	⅝	1¾	0.48	9	1¾	4¾	2¾	10½	⅝	1¾	0.48	4.27	¾	4	1¾
10¾	½	1½	0.39	7½	1½	4½	2	10¾	½	1½	0.39	3.48	⅝	3½	1½
10a	⅜	1⅜	0.29	6	1¼	4	1¾	10a	⅜	1⅜	0.29	3.00	½	3	1¼
10b	⅜	1¼	0.23	4½	⅞	3½	1⅜	10b	⅜	1¼	0.23	2.50	⅜	2¾	1
	⅜	1	0.16	3	¾	3	1⅛		⅜	1	0.16	1.75	⅜	1¾	1
									¼	¾	0.09	1.00	⅛	1½	¾

TRANSMISSION OR STANDING ROPE.

WITH 6 STRANDS OF 7 WIRES EACH.



CAST STEEL.							IRON.						
Trade No.	Diameter, in Inches.	Circumference, in Inches.	Estimated Weight per Foot, in Pounds.	Breaking Stress, in Tons of 2,000 Pounds.	Proper Working Load, in Tons of 2,000 Pounds.	Circumference of Hemp Rope of Equal Strength.	Trade No.	Diameter, in Inches.	Circumference, in Inches.	Estimated Weight per Foot, in Pounds.	Breaking Stress, in Tons of 2,000 Pounds.	Proper Working Load, in Tons of 2,000 Pounds.	Circumference of Hemp Rope of Equal Strength.
11	1½	4¾	3.37	62	13	15	11	1½	4¾	3.37	36	9	10¾
12	1⅜	4¼	2.77	52	11	13	12	1⅜	4¼	2.77	30	7½	10
13	1¼	4	2.28	44	9	12	13	1¼	4	2.28	25	6¼	9¼
14	1⅛	3½	1.82	36	7	10¾	14	1⅛	3½	1.82	20	5	8
15	1	3⅛	1.50	30	6	10	15	1	3⅛	1.50	16	4	7
16	⅞	2¾	1.12	22	4⅜	8½	16	⅞	2¾	1.12	12.3	3	6¼
17	¾	2⅜	0.92	17	3½	7¼	17	¾	2⅜	0.92	9	2¼	5¼
18	11/16	2⅛	0.70	14	2¾	6½	18	11/16	2⅛	0.70	7.6	2	5
19	5/8	2	0.57	11	2	5½	19	5/8	2	0.57	5.8	1½	4¾
20	9/16	1¾	0.41	8	1¾	5	20	9/16	1¾	0.41	4.1	1	4
21	½	1½	0.31	6	1¼	4¾	21	½	1½	0.31	2.83	¾	3¼
22	7/16	1⅜	0.23	5	1	4¼	22	7/16	1⅜	0.23	2.13	½	2⅜
23	⅜	1⅛	0.21	4	⅞	3¾	23	⅜	1⅛	0.21	1.65	½	2½
24	5/16	1	0.16	3	¾	3¼	24	5/16	1	0.16	1.38	½	2¼
25	1/4	⅞	0.12	2¾	⅝	2¾	25	1/4	⅞	0.12	1.03	⅜	2

Ropes of High Tensile Strength.

"PLOUGH STEEL" GRADE.

Trade No.	Diameter, in Inches.	Estimated Weight per Foot, in Pounds.	Breaking Stress, in Tons of 2,000 Pounds.	Proper Working Load, in Tons of 2,000 Pounds.	Minimum Diameter of Drum or Sheave, in Feet.
WITH 6 STRANDS OF 19 WIRES EACH.					
1	2¼	8.00	230	46	12
2	2	6.30	185	37	12
3	1¾	5.25	155	31	11
4	1⅝	4.10	125	25	11
5	1½	3.65	115	23	10
5½	1⅜	3.00	95	19	9
6	1¼	2.50	76	15	8
7	1⅛	2.00	63	12½	7
8	1	1.58	50	10	6
9	⅞	1.20	42	8½	6
10	¾	0.88	30	6	5½
10¼	⅝	0.60	23	4½	5
10⅜	9/16	0.44	15	3	4½
10¾	½	0.35	12	2½	4
10a	7/16	0.29	10	2	3½
10b	⅜	0.26	8	1½	3
WITH 6 STRANDS OF 7 WIRES EACH.					
11	1½	3.37	103	20½	12
12	1⅜	2.77	86	17	11½
13	1¼	2.28	70	14	11
14	1⅛	1.82	60	12	10½
15	1	1.50	45	9	10
16	⅞	1.12	33	6½	9
17	¾	0.88	25	5	8
18	11/16	0.70	21	4	7½
19	⅝	0.57	16	3	7
20	9/16	0.41	13	2½	6½
21	½	0.31	9	1¾	6
22	7/16	0.28	8	1½	5
23	⅜	0.19	7	1¼	4
24	5/16	0.16	5	1	3½
25	5/32	0.12	4	¾	3

Galvanized Wire Rope.

WITH 6 STRANDS OF 7 OR 12 WIRES EACH.

FOR SHIPS' RIGGING, GUYS FOR DERRICKS, ETC.

Circumference, in Inches.	Estimated Weight per Fathom, in Pounds.	Estimated Weight per Foot, in Pounds.	Circumference of Hemp Rope of Equal Strength, in Inches.	Breaking Stress, in Tons of 2,000 Pounds.	Approximate Diameter, in Inches.
5½	26½	4.42	11	43	1.75
5¼	24½	4.08	10½	40	1.67
5	22	3.67	10	35	1.60
4¾	21	3.50	9½	33	1.51
4½	19	3.17	9	30	1.43
4¼	16½	2.75	8½	26	1.35
4	14¼	2.38	8	23	1.27
3¾	12¾	2.13	7½	20	1.19
3½	10¾	1.70	7	16	1.11
3¼	9½	1.58	6½	14	1.04
3	8	1.33	6	12	0.96
2¾	6¾	1.13	5½	10	0.88
2½	5½	0.92	5	8½	0.80
2¼	4½	0.75	4½	7	0.72
2	3½	0.59	4	6	0.64
1¾	2¾	0.42	3½	5	0.56
1½	1¾	0.30	3	3½	0.48
1¼	1¼	0.21	2½	2½	0.40
1⅛	1	0.17	2¼	2¼	0.36
1	11/16	0.14	2	2	0.32
⅞	¾	0.11	1½	—	0.28
¾	⅝	0.085	1¼	¾	0.24
⅝	½	0.06	1	⅝	0.20
½	7/16	0.045	¾	½	0.16

Galvanized Steel Cables.

FOR SUSPENSION BRIDGES.

Cables Laid up Like Wire Rope.			Cables Composed of Wires Laid Parallel and Bound Together.		
Diameter in Inches.	Ultimate Strength in Tons of 2,000 Pounds.	Weight per Foot in Pounds.	Diameter in Inches.	Ultimate Strength in Tons of 2,000 Pounds.	Weight per Foot in Pounds.
2⅝	220	11.7	4	760	35.26
2½	200	10.3			
2⅜	180	9.2	3¾	665	30.78
2¼	155	8.3			
2	110	6.5	3½	580	26.23
1⅞	100	5.8	3	400	18.34
1¾	95	5.6			
1⅝	75	4.3	2¾	325	15.40
1½	65	3 7	2½	262	12.88

We are prepared to make estimates and designs for suspension bridges of all descriptions.

If required, we can furnish competent engineers to superintend their construction.

Applications for estimates should state length of span between towers, width of roadway, character of traffic and maximum load. They should, if possible, be accompanied by a profile on the center line of the proposed structure, which line should extend back far enough to determine the location of the anchorages. The profile should show high and low water, and the kind of material composing the banks and bed of the stream.

Flat Ropes.

Size, in inches.	Approximate weight per foot, in Pounds.	Breaking Stress, (Approximate) in Pounds.	
		Iron.	Cast Steel.
2 x⅜	1.35	20,000	40,000
2½x⅜	1.70	25,000	50,000
3 x⅜	2.05	30,000	60,000
3½x⅜	2.40	35,000	70,000
4 x⅜	2.75	40,000	80,000
5 x⅜	3.45	50,000	100,000
6 x⅜	4 15	60,000	120,000
3 x½	2.40	37,500	75.000
3½x½	2.85	43,750	87,500
4 x½	3.30	50,000	100.000
5 x½	4.20	62,500	125,000
6 x½	5.10	75,000	150,000
7 x½	6.00	87,500	175,000
8 x½	6 90	100,000	200,000

For safe working load allow from one-fifth to one-seventh of the breaking stress.

"LANG-LAY" ROPE.

A preference has recently been manifested, both in this country and abroad, for the use, under certain conditions, of a style of wire rope differing from the ordinary wire rope in the manner of laying up. In wire rope, as ordinarily made, the component strands are laid up into rope in a direction opposite to that in which the wires are laid into strands; that is, if the wires in the strands are laid from right to left, the strands are laid into rope from left to right. In the particular style of rope above referred to, the wires are laid into strands and the strands into rope in the same direction; that is, if the wire is laid in the strands from right to left, the strands are also laid into rope from right to left. The subjoined cuts show the difference between the two methods of laying up. In England this style of rope has been known as "Lang-lay"; in this country sometimes as "Lang-lay" and sometimes as "Universal lay." Its use has been found desirable under certain conditions and for certain purposes, mostly for haulage plants, inclined planes, and street railway cables, although it has also been used for vertical hoists in mines, etc. Its advantages are that it is somewhat more flexible than rope of the same diameter and composed of the same number of wires laid up in the ordinary manner; and (especially) that owing to the fact that the wires are laid more axially in the rope longer surfaces of the wires are exposed to wear, and the endurance of the rope is thereby increased. The difference between the "Lang-lay" and the ordinary lay wire rope when new, and the appearance of the former after being subjected to a lengthened period of wear, are shown in the cuts on next page. The ordinary rope shows in use a tendency in the component wires to break on the crowns of the strands, which tendency is in the "Lang-lay" rope very much diminished. In consequence of its greater flexibility, moreover, fewer wires may be used in the strands of the "Lang-lay" rope; in fact it is almost always made with 7 wires to the strand, although occasionally with 12. There are, on the other hand, some drawbacks to the use of the "Lang-lay" rope; it cannot be spliced to a rope of the ordinary lay, and it is in itself somewhat more difficult to handle and splice, owing to the fact that great care has to be taken to prevent unwinding of the strands, which is apt to occur unless the rope is well served or otherwise secured behind the place where the splice is to be made.

Fig. 102. "Lang-Lay" Rope, New.

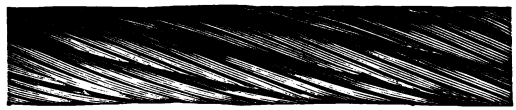


Fig. 103. "Lang-Lay" Rope, Worn.

Fig. 104. Rope of Ordinary Lay, New.

PATENT LOCKED WIRE ROPE.

Fig. 105 illustrates the construction of our patent locked wire rope, so named from the fact that the exterior wires are drawn to such a shape that each one interlocks with its neighbor in such a way as to present a smooth cylindrical surface like a solid round bar. This rope will not only outwear two to three ordinary ropes, but, on account of its smooth surface, the life of the sheaves and rollers over which it runs, or which traverse it as the case may be, is also proportionately greater, which is an important item to be taken into consideration. The wires are

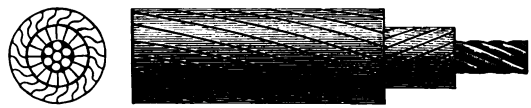


Fig. 105. Patent Locked Wire Rope.

made of the best tempered cast steel, and it is evident that with this construction such a thing as unstranding is impossible. Should any of the wires break, which rarely happens, it cannot result in projecting ends and a ragged surface as in the case of ordinary ropes. Another advantage it possesses is that it has no tendency to twist in working as ordinary ropes have. These ropes have wire cores, and on this account are somewhat stiffer than ordinary ropes of the same size; but they are also much stronger. Compared with ordinary ropes of equal strength, the locked wire rope is quite as flexible. In the ordinary ropes the strength is only about 80 per cent. of the aggregate strength of the individual wires, whereas in the locked wire ropes it is about 95 per cent., and in substituting the locked wire ropes for ordinary ropes, therefore, a size smaller should be used.

This rope cannot be spliced like ordinary rope, but joints are readily made by means of steel couplings, as illustrated in Fig. 106.

Inquiries for locked wire rope should always state the purpose for which it is intended, diameter of drums and sheaves employed, and size and style of rope hitherto used. The following table gives the weight, strength, etc. of the different sizes.

Fig. 106. Locked Wire Rope Coupling.

Diameter, Inches,	Estimated Weight per Foot, Pounds.	Breaking Stress (approximate) in Tons of 2,000 Pounds.	Proper Working Load, in Tons of 2,000 Pounds.	Minimum Diameter of Drum or Sheave, in feet.
2	10.00	157	31.00	12
1½	5.35	95	19.00	8
1⅜	4 50	80	16.00	8
1¼	3.67	67	13.40	7
1⅛	2 90	55	11.00	6
1	2.35	43	8.60	5
⅞	1.78	36	6.60	4
¾	1.29	27	4.80	3½
⅝	0 90	19	3.40	3
9/16	0 72	13¼	2.65	2¾
½	0.57	11½	2.10	2⅛

[Copy.]

Lemont, Ill. 5–13–1896.

Trenton Iron Co., Chicago, Ill.:

Gentlemen—Your letter of the 6th inst. received upon the writer's return here.

In reference to the efficiency of the "Patent Locked Cable" furnished us by your Company, will say that results obtained by its use have been very satisfactory to us. We have conveyed an amount of over 80,000 cubic yards over this line with little or no perceptible wear on the cable. Yours respectfully,

MASON, LOCHER & WILLIAMSON.
C. H. Locher.

Louisville, Ky., May 26th, 1896.

Trenton Iron Company, Trenton, N. J.:

Gentlemen—Replying to your favor 18th inst., regarding the two inch Patent Locked Wire Rope you furnished for our cable line: This rope has been in use about one year, during which time our cable line

has been bringing the raw material to the cupolas and carrying offal from our shop. We take pleasure in writing that this cable line has given very satisfactory service. Yours respectfully,

DENNIS LONG & COMPANY,
By A. F. CALLAHAN, *Vice-Pres't.*

[COPY.]

ROCKLAND, ME., April 12, 1895.

TO WHOM IT MAY CONCERN:

This is to certify that we have hoisted fully one hundred and fifty thousand (150,000) tons of limestone over the Locke cable tramway, erected for us by the Trenton Iron Co., at our Engine Quarry. This output covers a period of about five years, and there is as yet no apparent wear upon the cable. Yours truly,

COBB LIME CO.,
H. N. PIERCE, *Sec'y.*

From the GAULEY MOUNTAIN COAL CO., FAYETTE COUNTY, W. VA.
Telegraph Office, Hawk's Nest.

ANSTED, FAYETTE COUNTY, W. VA., April 15th, 1892.

THE TRENTON IRON CO., TRENTON, N. J.:

Gentlemen—Answering your inquiry of the 12th inst., beg leave to say that under similar work and conditions I would estimate the life of an ordinary twisted steel rope at about three years, and be satisfied with such service. Your locked wire rope has been in constant use nearly two years, and shows no sign of wear or failure; not a strand having given away as yet. From present appearances, I think it will continue its service three years longer, or a total life of five years.

Comparatively speaking, there is little or no wear on the sheaves and rollers. The latter, made of five-inch wrought pipe, have never been renewed, and are very little worn, while the sheaves have not been re-filled, with an average service of about 240,000 feet daily for the two, or 120,000 feet each.

It is uncertain as yet when we shall require an additional plane, upon which I expect to use the same rope.

Yours truly,

WM. N. PAGE.

From the CENTRAL MINING Co. (Copper), Central Mine Post-office, Mich., John Stanton, Treas., Nov. 10th, 1891.

"The rope is 1¼ inches in diameter, and has been in use about thirteen months, under the following conditions, viz.: The hoist is direct acting, *i. e.*, the rope winding on a conical drum placed on crank shaft, the smallest diameter of drum being 14 feet. Rope passes over a 10-foot pulley directly down a vertical shaft about 300 feet from drum. The shaft is about 2,900 feet deep. Cage and ore weigh about 6½ short tons. The hoist is in constant use day and night; usual speed averages about 2,500 feet per minute. Under these conditions, the rope shows no perceptible wear, and the wear on the pulleys is very small. Under the same conditions the wear of ropes made in the ordinary form has always been much greater, while the pulleys not only wear out very rapidly, but from their uneven wear cause more or less jerking and thrashing motion of the rope, and of course greater strains upon it. It is too soon to tell what the life of the rope will be, but under the conditions I have named, *i. e.*, hoisting heavy loads with high speed, I am convinced of its great superiority over the ordinary form of rope."

WIRE ROPE FITTINGS.

The different methods of making attachments to wire ropes is a subject the importance of which is too often overlooked. Two distinct kinds of fittings are used: the Thimble, Figs, 107, 108 and 109; and the Socket, Figs. 110 to 115, inclusive. Of the former there are three methods of securing the thimbles: one (Fig. 107) is by simply bending the end of the rope around the thimble and fastening with clips; another (Fig. 108), by fraying out the wires a short distance at the end, bending the rope around the thimble, laying the straightened wires snugly about the main portion of the rope, and finally serving or wrapping with suitable wire and bending back the extreme ends of the wires projecting beyond the portion wrapped; the third method (Fig. 109) is by interlocking the strands in the manner of a splice, and serving the whole with wire. The latter method is the most difficult attachment to make, but possesses the greatest strength, and if well done is as strong as the rope itself.

It is not always practicable to use thimbles, especially with large and unwieldy ropes, in which case attachments are made by means of sockets; and these are generally preferred for the smaller ropes also, on account of being easier to put on and neater in appearance. The ordinary socket (Figs. 110 and 111) consists of a funnel-shaped forging or steel casting with a loop or open prongs at the wide end, designated respectively as loop sockets and open sockets with keys. The rope is secured by fraying out the wires at the end for a distance equal to about twice the length of the socket aperture, observing the precaution first to serve the rope at the point where the straightened wires begin and the unfrayed-out strands terminate. Some of the wires are then trimmed off to shorter lengths, and all bent back upon themselves, hook-fashion, so that the resulting bunch will conform as near as possible to the conical shape of the socket This bunch is then drawn into the socket, a conical plug rammed in the core, spreading the wires out tightly against the sides of the socket, and the whole finally cemented with molten Babbitt metal.

In the case of ropes made of large, stiff wires, the ends are simply straightened out and the interstices filled with narrow, tapering pins or wedges. Our patent interlocked and smooth coil tramway cables are

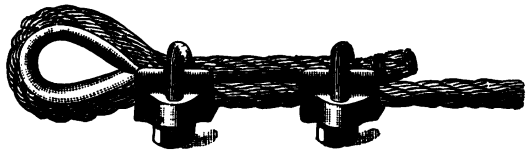


Fig. 107. The Crosby Wire Rope Clip.

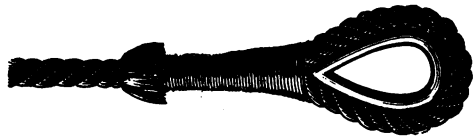


Fig. 108. Thimble.

Fig. 109. Thimble.

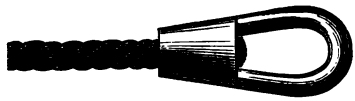


Fig. 110. Loop Socket.

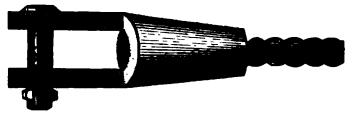


Fig. 111. Open Socket, With Key.

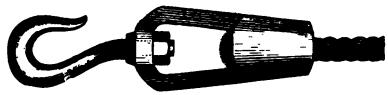


Fig. 112. Socket and Swivel Hook.

Fig. 113. Socket and Hook.

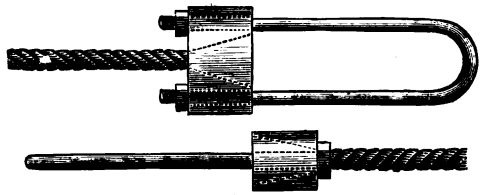


Fig. 114. Loop Stirrup.

Fig. 115. Open Stirrup.

Fig. 116. Coupling For Interlocked Cable.

Fig. 117. Wire Rope Clamps.

Fig. 118. Turn-buckle.

socketed in this way, the wedges and conical rings being made approximately to the shape of the interstices, binding all the wires uniformly, so that no Babbitt metal is required. Fig. 116 illustrates the patent coupling, for joining sections of our patent interlocked tramway cable referred to on page 9, and consists simply of two narrow cast steel sockets, joined at the center by a plug with right and left hand threads. The act of screwing up the plug drives home the wedges so firmly that it is a very rare occurrence for a wire to pull out.

A socket sometimes used is shown in Fig. 30, page 90, and consists of a pair of tapering trough-shaped tongs, bent to a loop at the center, and attached to the rope by pins or rivets. The pins are driven cold, after the strands have been forced apart by a spike, the end of the rope being soldered to prevent the strands untwisting. This socket possesses the merit of being compact and easily put on, but it is not as strong as the other and can only be recommended where the strains are light.

Fig. 117 illustrates a clamp used on the larger sizes of ropes with special attachments, and Fig. 118 a turn-buckle, such as used in adjusting the tension of a wire rope.

Attachments to the patent locked-wire rope are made by means of sockets, Figs. 119 and 120, and special care is required in putting these on, for if improperly done and any of the wires become slack, the rope will soon give out. The following directions, therefore, should be carefully observed:

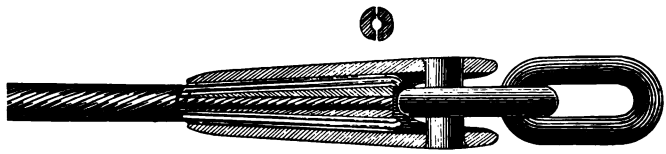


Fig. 119

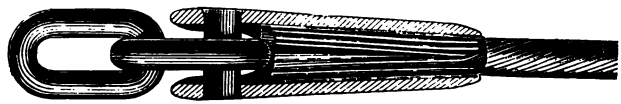


Fig. 120. Sections of Coupling Sockets.

DIRECTIONS FOR SOCKETING PATENT LOCKED WIRE ROPES.

First.—Care should be taken to see that the socket is of the right size for the rope it is to be put on. (All sockets furnished by us have the diameter of the rope they are intended for either stamped or cast on them.)

Second.—Make sure that the inside of the socket is perfectly smooth and free from grease or rough spots.

Third.—When ready, heat the socket gently and regularly on all sides up to about 300 degrees; at this heat a piece of paper placed on it will scorch, but should not char or ignite.

Fourth.—Prepare a ladle of melted Babbitt metal, or any hard alloy of sufficient capacity to fill the socket when the rope is in place. The metal should be heated to its greatest point of fluidity.

Fifth.—Now take the rope and serve the end to be socketed with a strong and tight serving, previous to cutting off, which should be done with an ordinary hack saw. Then, measuring back from the end a distance equal to the length of the socket, put on one or two clamps tight enough to prevent any slack from the outside wires running back into the rope. Now secure this clamp in a vise, or other convenient appliance, and then slip on the coupling, unwinding the wire serving as the rope is pushed in. When the end of the socket rests against the clamp, the end of the rope should be nearly flush with the mouth of the bell. See Fig. 122.

The wires in the rope should now be opened out by inserting a a long, tapered marlin spike in the center, care being taken to distribute the wires as evenly as possible all around the inside of the socket. Then the center pin, C, Fig. 122, which should also have been heated by dipping it for a while in the molten metal, is inserted in the place of the marlin spike, and gradually driven home with light blows at first, and finally with all the power necessary to run it flush with the top of the socket. Finally, while everything is still hot, pour in the molten metal, so that all the interstices are filled completely (Fig. 123). When this is done, cool off the socket from the outside by sprinkling water over it.

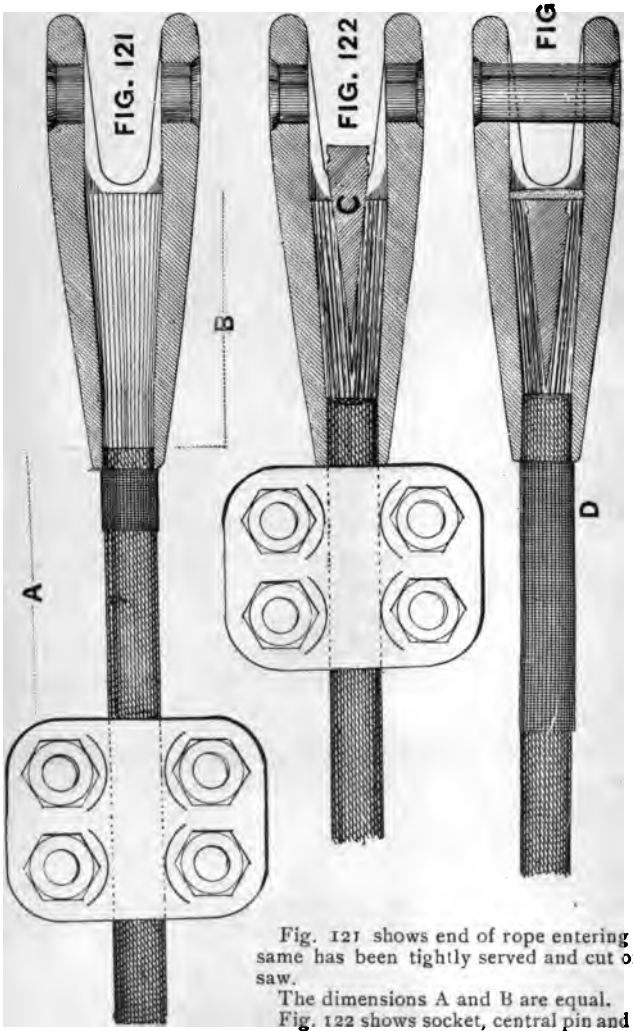


Fig. 121 shows end of rope entering socket after same has been tightly served and cut off with hack saw.

The dimensions A and B are equal.

Fig. 122 shows socket, central pin and part of rope in section.

Fig. 123, socketing completed, showing socket, Babbitt, central pin and part of rope in section.

Sixth.—When the socketing is completed, remove the clamps, and serve the rope for a distance of four or five inches with strong wire, so as to prevent any possible slack from any cause running back into the rope, as at D, Fig. 123.

After the rope has been put in service, under strain, it will probably pull through the socket a distance about equal to its diameter before every wire comes to a bearing. Should it show any more slippage than this, then the socketing has been improperly made and should be done over again.

Where it is essential that all the wires should be made absolutely secure, the style of socket illustrated in Fig. 124 is used. This consists really of three or more sockets in steps, one behind the other, the larger for the outside wires, the following for the next larger, and so on down to the core. This style of socket can be relied upon in all cases to withstand any strain that the rope will safely bear.

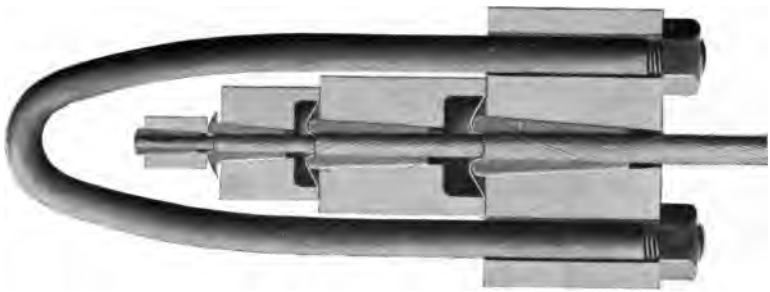


Fig. 124. Step Socket.

WIRE ROPE SHEAVES AND TACKLE BLOCKS.

We manufacture iron or steel sheaves and tackle blocks of every description. To illustrate all the various kinds would require more space than is at our command.

Our transmission wheels, Figs. 125 and 126, are neat in design, and as light as it is possible to make them consistent with the requisite strength. The rims are either filled with wood or with segmental blocks of rubber and leather, soaked in tar and laid in alternately. The latter filling is recommended for transmission of power, on account of its greater resistance to slippage, but for the terminal sheaves of wire rope tramways, where the pressure of the rope is greater, the wood filling has been found most satisfactory.

Our hoisting and derrick sheaves, Figs. 127 to 130 inclusive, are designed to resist heavy strains. The former are made with plain V grooves and ribbed arms, and the latter with solid webs and narrow flanges. Wood-lined hoisting sheaves are only made for special purposes.

We furnish tackle blocks, Figs. 131 and 132, of any desired size, with one, two, three or more sheaves, according to the number of desired parts in the rope, and grooved to fit the size used; with skeleton guards, or with wrought iron or steel plate shells; with beckets or shackles; with loose fronts or swivel hooks; with iron or phosphor-bronze bushings. We shall be pleased to quote prices for any of these on receipt of information as to just what is wanted.

THE EFFECT OF BENDING ON WIRE ROPES.*

We are frequently asked "how long a certain wire rope will last." This is a difficult question to reply to with any satisfaction, as the life of a wire rope is affected in various ways; for instance, by the

* From a paper, by Mr. William Hewitt, read before the Engineering Association of the South at Nashville, Tenn., March 12, 1896.

Sheaves for Transmission of Power.

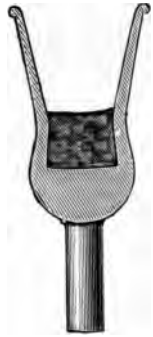


Fig. 125.

Fig. 126.

Iron Hoisting Sheaves.

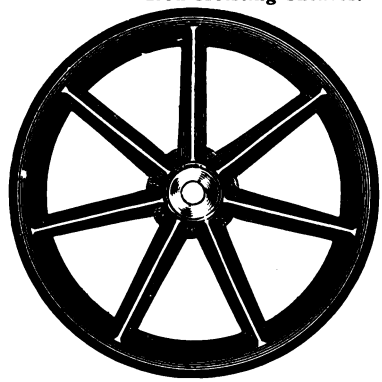


Fig. 128.

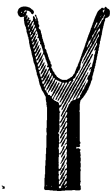


Fig. 127.

From three to five feet in diameter.

Iron Derrick Sheaves.

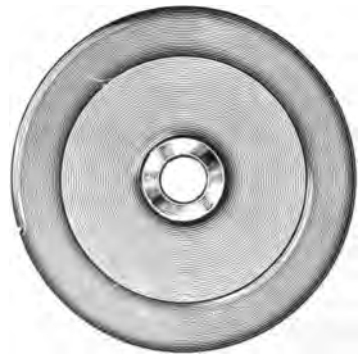


Fig. 130.

Fig. 129

From eight to thirty inches in diameter.

duty performed, the care taken of it, the amount and degree of bending it is subjected to, its exposure to the corroding action of water and more especially water containing salts or acids, etc., all of which, excepting the first, perhaps, are more or less uncertain factors upon which to base any kind of calculations.

The principal causes of wear are abrasion and excessive bending strains. Abrasion results in the flattening or tearing apart of the wires, while undue bending is manifested in the fracturing of the outer wires at the wearing points, as illustrated in Fig. 133. More wire ropes are probably worn out from undue bending than from abrasion, owing to the fact that space very often forbids the use of proper sized sheaves, and the additional cost of large sheaves, especially in mining plants, is frequently a serious objection to their use.

Fig. 133.

For good results, of course, the bending strain, added to the direct tension due to the load, should be within the elastic limit of the wires. The strain due to bending is very often considerably greater than that due to the useful effort or load, and the importance of the size and proper disposition of the sheaves used is a matter that should be carefully considered in any wire rope installation.

Ratio of Diameter of Sheave to Diameter of Wire.	Stress per Square Inch of Wire Section due to Bending.	Ratio of Diameter of Sheave to Diameter of Wire.	Stress per Square Inch of Wire Section due to bending.	Ratio of Diameter of Sheave to Diameter of Wire.	Stress per Square Inch of Wire Section due to Bending.	Ratio of Diameter of Sheave to Diameter of Wire.	Stress per Square Inch of Wire Section due to Bending.
648.	40500	960.	27650	1209.6	22200	1536.	17670
691.2	**38000**	1008.	26500	1296.	20800	1555.2	17390
720.	36480	1036.8	25940	1344.	19950	1584.	17100
768.	34200	1080.	24800	1382.4	19380	1612 8	16820
864.	30780	1152.	23370	**1440.**	**19000**	1680.	15960
921.6	28500	1200.	22230	1512.	17960	1728.	15680

The preceding table gives the stress per square inch of wire section in ropes, due to bending, for different ratios between the diameters of the wires and sheaves, the ratios selected being those most commonly occurring in practice.

Wire Rope Snatch Block.

Fig. 131.

Fig. 132.

For ordinary wire ropes the ratios between the diameters of the rope and the individual wires are approximately as follows:

7 wires to the strand, 1–9
12 " " " " 1–12
19 " " " " 1–15

The figures in heavy-faced type correspond with maximum efficiency in the transmission of power under ordinary conditions (see page 156).

The angle that a wire rope makes in bending is also a matter to be taken into consideration. It has been asserted that the degree of bending makes no difference; in other words, that the tension due to

bending will be the same whether the rope merely touches the sheave or wraps all the way around it, which would be so under the assumption that the rope bends to the curvature of the sheave; but the fact is that the curvature is dependent on the tension, and with certain relative proportions, between the tension and bending angle, the curvature is not necessarily the same as the sheave in contact, but something greater, which explains how it is that large ropes are frequently run around comparatively small sheaves without detriment, since it is possible to place these so close that the bending angle on each will be such that the resulting curvature will not overstrain the wires. This curvature may be ascertained from the following table, which gives the theoretical radii of curvature in inches for various sizes of ropes and different angles for one pound tension in the rope. Dividing these figures by the actual tension in pounds, gives the radius of curvature assumed by the rope in cases where this exceeds the curvature of the sheave. These figures can only be considered as approximate, however, since the rigidity of the rope or internal friction of the strands and core has not been taken into account. Just what this amounts to it is impossible to say from the meagre information at hand and the various formulæ for determining it, given by the different authorities, are all more or less uncertain and indefinite. It seems to be agreed, however, that the resistance of rigidity is the sum of two quantities, one constant and the other varying with the tension, and that the constant values are dependent on the condition of the rope. For new wire rope Weisbach gives an example showing this resistance as amounting to $5\frac{8}{10}$ lbs. for a tension of 2,000 lbs. The actual curvature, therefore, for any given load will probably be slightly greater than the curvature ascertained by the table.

TABLE FOR DETERMINING CURVATURE OF WIRE ROPES FOR DIFFERENT ANGLES.

19–Wire Rope.	90°	100°	110°	120°	125°	130°	135°	140°	145°	150°	155°	160°	165°	170°	175°
½	1038	1142	1280	1468	1626	1736	1918	2146	2441	2836	3391	4226	5623	8421	16825
⅝	2723	2996	3357	3851	4170	4556	5032	5630	6404	7440	8897	11090	14753	22095	44178
¾	5470	6017	6743	7736	8377	9151	10107	11309	12863	14944	17870	22274	29633	45412	88673
⅞	10605	11666	13074	14998	16240	17742	19596	21925	24938	28974	34647	43184	57451	86040	171917
1	17636	19401	21742	24941	27007	29506	32587	36462	41471	48183	57617	71816	95541	143085	285897
1⅛	27692	30463	34138	39162	42406	46329	51168	57251	65117	75655	90469	112763	150016	224667	448907
1¼	41535	45692	51205	58740	63606	69489	76747	85872	97670	113477	135696	169135	225012	336982	673323
7–Wire Rope.															
½	3171	3488	3909	4485	4856	5306	5859	6556	7457	8663	10360	12914	17179	25727	51405
⅝	7309	8040	9010	10336	11193	12229	13505	15111	17187	19968	23878	29762	39594	59297	118482
¾	15302	16834	18865	21641	23434	25604	28275	31637	35984	41807	49993	62313	82899	124151	248066
⅞	28545	31402	35191	40277	43714	47761	52745	59016	67124	77988	93258	116239	154641	231593	462745
1	48949	53847	60344	69224	74959	81899	90446	101199	115103	133731	159915	199323	265173	397129	793501
1⅛	78721	86598	97047	111328	120551	131712	145457	162751	185111	215069	257180	320556	426459	638674	1276131
1¼	123869	136263	152706	175177	189689	207252	228880	256092	291276	338416	404679	504402	671041	1004965	2008017

The figures in this table are the radii in inches for one pound tension. To obtain the actual radius of curvature in any case, divide by the stress in pounds.

Transmission of Power by Wire Rope.

It is evident from the foregoing that in transmitting power by means of wire rope, the working tension or force transmitted should not exceed the difference between the elastic limit of the material and the bending stress, as given in the table on page 152. The working tension may be greater, therefore, as the bending tension is less, but in ordinary flying transmissions where the rope makes a single half lap on the sheaves, the tension in the slack portion of the rope cannot be less than one-half the tension in the taut portion, otherwise the rope would slip. A certain ratio exists, therefore, between the diameter of the sheaves and the wires composing the rope, corresponding to a maximum safe working tension, and this ratio it can be demonstrated is one resulting in a maximum working tension of approximately one-third the elastic limit of the material; in other words, under the most favorable conditions the bending stress will be double the working tension. Taking the elastic limit of tempered steel, such as used in the best rope, at 57,000 pounds per square inch, and that of Swedes iron at one-half this, or 28,500 pounds, the corresponding diameters of sheaves are given in the following table:

DIAMETERS OF MINIMUM SHEAVES IN INCHES, CORRESPONDING TO A MAXIMUM SAFE WORKING TENSION.

Diameter of Rope.	Steel.			Iron.		
	7-Wire.	12-Wire.	19-Wire.	7-Wire.	12-Wire.	19-Wire.
1/4	19	14	12	40	30	24
5/16	24	18	14	50	38	30
3/8	29	22	17	60	45	36
7/16	34	25	20	70	53	42
1/2	38	29	23	80	60	48
9/16	43	32	26	90	68	54
5/8	48	36	29	100	75	60
11/16	53	40	32	110	83	66
3/4	58	43	35	120	90	72
7/8	67	50	40	140	105	84
1	77	57	46	160	120	96

It appears from this, contrary to the ordinary belief, that iron rope requires larger sheaves than steel rope does. This is due to the fact that iron wire, while having the same modulus of elasticity as steel, possesses but half the ultimate strength. There are practical reasons, however, for advocating in most cases the use of somewhat larger sheaves for steel rope than given in the above table,—the recoil, for instance, when suddenly released of tension, owing to the springy nature of the material, which might cause the rope to jump off the sheaves,—but this does not apply to ordinary transmissions of power, and it is curious to note that iron rope is still recommended by some for this purpose. This is to be explained, perhaps, by the fact that objections have heretofore been urged against the use of steel on account of its lack of homogeneity which caused it to become brittle under continuous bending, while iron, owing to its greater ductility, will simply elongate for a considerable period without having its strength seriously impaired. On the other hand, this process of elongation requires frequent taking-up or re-splicing which is very objectionable. We use a special grade of homogeneous tempered steel wire, possessing high tensile strength with great ductility, that practice has demonstrated to be superior to iron for the transmission of power, and since it admits of the use of smaller sheaves it is to be preferred, as the saving in the cost of the sheaves will much more than offset the additional cost of the rope.

Under ordinary conditions ropes of seven wires to the strand, laid about a hemp core, are best adapted to the transmission of power, but special conditions occur very often where ropes of twelve or nineteen wires to the strand are to be preferred.

The tension of the rope is measured by the amount of sag or deflection at the center of the span, and the deflection corresponding to the maximum safe working tension is determined by the following formulæ, in which S represents the span in feet.

	Steel Rope.	Iron Rope.
Def. of still rope at center, in feet....	$h = \cdot 00004\ S^2$	$h = \cdot 00008\ S^2$
" driving " " "	$h_1 = \cdot 000025\ S^2$	$h_1 = \cdot 00005\ S^2$
" slack " " "	$h_2 = \cdot 0000875 S^2$	$h_2 = \cdot 000175 S^2$

In laying out a transmission of power it is necessary to take into consideration the conditions governing the limits of span. When the

deflections are very small, as on spans of less than sixty feet for instance, it is impossible to splice the rope to such a degree of nicety as to give exactly the required deflection, and as the rope is further subject to a certain amount of stretch, it becomes necessary in such cases to apply mechanical means for producing the proper tension in the rope, in order to avoid frequent splices, which are very objectionable; but care should always be exercised in using such tightening devices, that they do not become the means, in unskilled hands, of overstraining the rope. When it is inconvenient to apply tightening devices, the sheaves may be refilled with a thicker filling, or a temporary lining put in by nailing to the filling already in, and the rope run on this as long as possible, when this lining is removed, the rope respliced, and placed again on the original filling. On the shorter spans, moreover, the rope is more sensitive to every irregularity in the sheaves and the fluctuations in the amount of power transmitted, and is apt to sway to such an extent beyond the narrow limits of the required deflections as to cause a jerking motion, which is very injurious to the rope. For this reason on very short spans it is found desirable to use a considerably heavier rope than what is actually required to transmit the power; or in other words, instead of a 7-wire rope corresponding to the conditions of maximum tension, it is better to use a 19-wire rope of the same size wires, and to run this under the 7-wire rope tension. In this way is obtained the advantages of increased weight and less stretch without having to use larger sheaves, while the wear will be greater in proportion to the increased surface.

In determining the maximum limit of span, the contour of the ground, and the available height of the terminal sheaves must be taken into consideration. It is customary to transmit the power through the lower portion of the rope, as in this case the greatest deflection in this portion occurs when the rope is at rest. When running, the lower portion rises and the upper portion sinks, thus enabling obstructions to be avoided which otherwise would have to be removed, or make it necessary to erect very high towers. The maximum limit of span in this case is determined by the maximum deflection that may be given to the upper portion of the rope when running. Assuming the clearance between the upper and lower portions of the rope should not be less than one foot, and that the sheaves are 10 feet in diameter, h_1 and h_2 repre-

senting respectively the deflections of the taut and slack portions of the rope,

we have $h_1 + 10 = h_2 + 1$,
or since $h_2 = 2\, h_1$,
we have $h_1 = 9$ feet.

This deflection for a steel rope corresponds to a span of 600 feet.

Much greater spans than this, however, are practicable where the contour of the ground is such that the upper portion of the rope may be the driver, and there is nothing to interfere with the proper deflection of the under portion, as for instance in crossing a ravine. Some very long transmissions of power have been effected in this way without an intervening support. There is one at Lockport, N. Y., with a clear span of 1,700 feet, and another near this of about 1,200 feet.

When the distance is greater than the limit for a clear span, it becomes necessary to introduce intermediate supporting sheaves, and as a rule the driving portion of the rope requires a less number of supports than the slack portion. Usually it will be found sufficient to support only the slack portion. These supporting sheaves may generally be replaced to advantage by intermediate stations, as shown in Figs. 134 and 135. The rope thus, instead of running the whole length of the

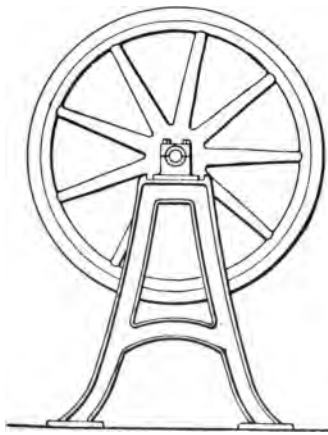


Fig. 134.

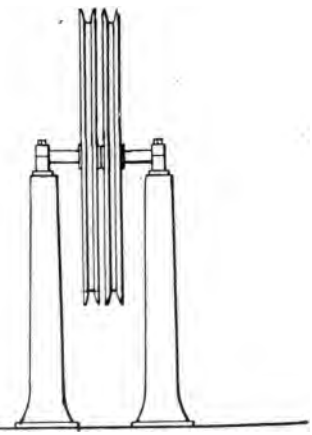


Fig. 135.

transmission, runs only from one station to the other, which should be equidistant, as far as practicable, so that a rope may be kept on

hand, ready spliced, to put on any span, should its rope give out. This method also prevents sudden fluctuations of motion being transmitted over the entire line.

It frequently happens that it is impracticable to use sheaves corresponding to the maximum safe working tension of the rope, in which case smaller ones may be used, but it will be understood of course that the wear of the rope will be more rapid.

Transmission sheaves should be well balanced; otherwise uneven wear will result in the bearings, and also in the filling, causing the rope to sway violently. If the splice is poorly made, the filling roughly inserted, or the sheaves bored untrue, similar irregularities in motion will result. It should be borne in mind that no pains should be spared at the outset to secure the careful alignment and equal balance of the sheaves, on account of the high velocities at which they are run.

Assuming the sheaves to be of equal diameter, and not smaller than consistent with the maximum safe working tension of the rope as determined by the table on page 156, *the actual horse-power that may be transmitted by a steel rope on wood-filled sheaves approximately equals* $6\frac{7}{10}$ *times the square of the diameter of the rope in inches multiplied by the velocity in feet per second.* From this rule we deduce the following:

Diam. of Rope.	Velocity of Rope in Feet per Second.									
	10	20	30	40	50	60	70	80	90	100
¼	4	8	13	17	21	25	28	32	37	40
5/16	7	13	20	26	33	40	44	51	57	62
⅜	10	19	28	38	47	56	64	73	80	89
7/16	13	26	38	51	63	75	88	99	109	121
½	17	34	51	67	83	99	115	130	144	159
9/16	22	43	65	86	106	128	147	167	184	203
⅝	27	53	79	104	130	155	179	203	225	247
11/16	32	63	95	126	157	186	217	245	272	299
¾	38	76	103	150	186	223	258	290	321	355
⅞	52	104	156	206	257	306	354	400	446	489
1	68	135	202	268	333	397	460	520	578	634

The horse-power that may be transmitted by iron ropes is one-half of the above.

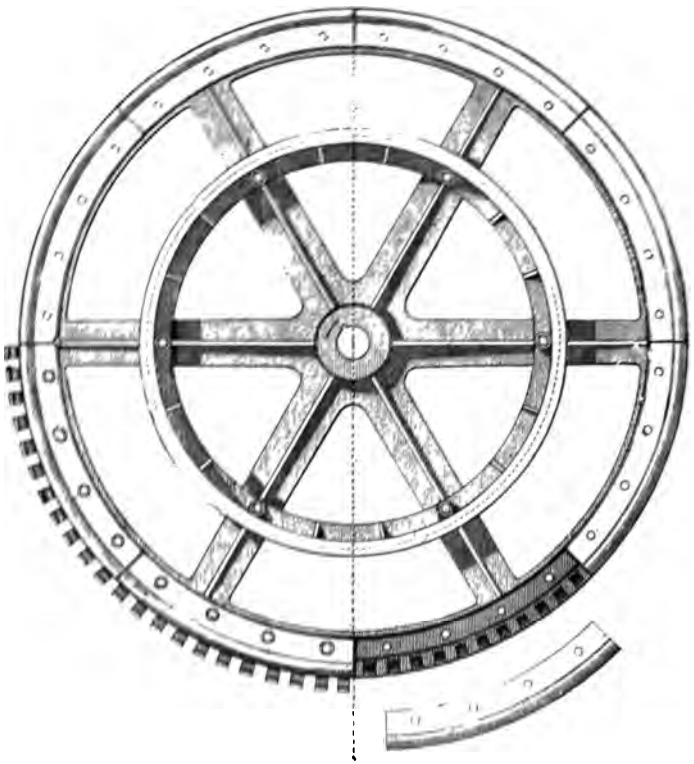
This table gives the amount of horse-power transmitted by wire ropes under maximum safe working tensions. In using wood-lined sheaves, therefore, it is well to make some allowance for the stretching

of the rope, and to advocate somewhat heavier equipments than the above table would give ; that is, if it is desired to transmit 20 horse-power, for instance, to put in a plant that would transmit 25 to 30 horse-power, thus avoiding the necessity of having to take up a comparatively small amount of stretch. On rubber and leather filling, however, the amount of power capable of being transmitted is 40 per cent. greater than for wood, so that this filling is generally used, and in this case no allowance need be made for stretch, as such sheaves will likely transmit the power given by the table, under all possible deflections of the rope.

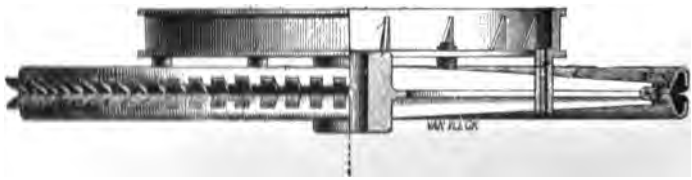
INCLINED TRANSMISSIONS.

It sometimes happens that the two wheels are not on the same horizontal plane, but that one occupies a higher elevation than the other. There will be a difference in the tensions in this case at the two wheels, the upper one being subject to a greater tension, but this difference is so slight, for all practicable spans, that it may be neglected so far as it affects the amount of horse-power that may be transmitted. It is evident, however, that when the angle of inclination is very great, the proper deflections cannot be readily determined, and the rope becomes more sensitive to the ordinary variations in the deflections, so that tightening sheaves must be resorted to for producing the requisite tension, as in the case of very short spans. In other words, the span to be considered in such cases is really the horizontal distance between the two wheels, and practice has shown that when this is less than sixty feet, or when the angle of inclination exceeds thirty to forty-five degrees, it will be found desirable to use tightening sheaves. The limiting case of inclined transmissions occurs when one wheel is directly above the other. The rope in this case produces no tension whatever on the lower wheel, while the upper is subject only to the weight of the rope, which is usually so insignificant that it might be neglected altogether without materially affecting the problem, and tightening sheaves are therefore an absolute necessity. If the rope and wheels are proportioned according to the preceding rules for maximum efficiency, the proper weight to be applied to the lower wheel in pounds, approximately equals the square of the diameter multiplied by 7,600, and for iron ropes one-half this.

PLAN.



GRIP PULLEY, WITH BRAKE-WHEEL.



SECTIONAL PLAN.

Figs. 136 and 137.

LONG-DISTANCE TRANSMISSIONS.

In very long transmissions of power the conditions do not always admit of obtaining the proper tensions required in the ordinary system, or "flying transmission of power," as it is termed. In other words, to obtain the proper conditions, it would necessitate numerous and expensive intermediate stations. In case, for instance, it is desired to utilize the power of a turbine to drive a factory, say a mile away, the best method is to employ a larger rope than would ordinarily be used, running it at a moderate speed. The rope thus may be in one continuous length, supported, at intervals of about a hundred feet, on sheaves of comparatively small diameter, since the greater rigidity of these ropes preserve them from undue bending strains. Where sharp angles occur in the line, however, sheaves must be used of a size corresponding to the safe limit of tension due to bending. The rope is run under a high working tension, far in excess of what in the ordinary system would cause it to slip on the sheaves. In other words, the working tension may be four or five times as great as the tension in the slack portion of the rope, and in order to prevent slipping, the rope is wrapped several times about grooved drums, or a series of sheaves at each end of the line. To provide for the slack due to the stretch of the rope, one of the sheaves is placed on a slide worked by long-threaded bolts, or, better still, on a carriage, provided with counterweights, which runs back and forth on a track. The latter preserves a uniform tension in the slack portion of the rope, which is very important. With our self-compensating arrangement of sheaves, any tendency of the rope to "creep," due to the irregular wear of the sheaves or drums, is avoided.

All wire rope tramways are practically transmissions of power of this kind, in which the load, however, instead of being concentrated at one terminal, is distributed uniformly over the entire line. Cable railways are also transmissions of this class.

The amount of horse-power capable of being transmitted is given by the formula :

$$N=[c\ D^2-.000006\ (w+g_1+g_2)]\ v,$$

in which D = diameter of the rope in inches, v = velocity of rope in feet per second, w = weight of the rope, g_1 = weight of the terminal

sheaves and shafts, g_2 = weight of the intermediate sheaves and shafts, and C = a constant depending on the material of which the rope is made, the filling of the sheaves, and the number of half laps of the rope on the driving sheave or drum. The values of c for one up to six half laps for steel rope are given in the following table:

c = for Steel Rope on	Number of Half Laps on the Driving Drum.					
	1	2	3	4	5	6
Iron.....	5.61	8.81	10.62	11.65	12.16	12.56
Wood	6.70	9.93	11.51	12.26	12.66	12.83
Rubber and Leather	9.29	11.95	12.70	12.91	12.97	13.

The values of c for iron rope are one-half the above.

It will be apparent from this table that when more than three half laps are made, the character of the surface in contact is immaterial as far as slippage is concerned.

From the above formula we have the general rule, that the actual horse-power capable of being transmitted by any wire rope approximately equals c times the square of the diameter of the rope in inches, less six-millionths the entire weight of all the moving parts, multiplied by the speed of the rope, in feet, per second.

Instead of grooved drums or a number of sheaves, about which the rope makes two or more laps, it is sometimes found more desirable, especially where space is limited, to use grip pulleys, such as illustrated in Figs. 136 and 137. The operation of these will be understood at a glance; the rim being fitted with a continuous series of steel jaws, which bite the rope in contact, by reason of the pressure of the same against them, but as soon as relieved of this pressure they open readily, offering no resistance to the egress of the rope.

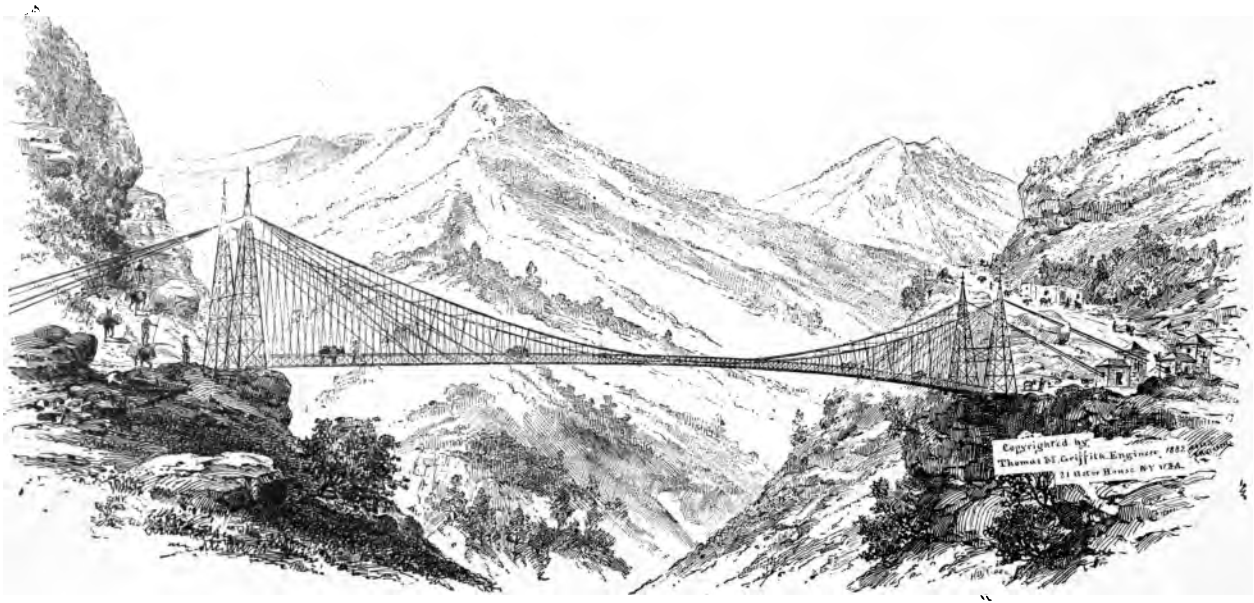


Fig. 138. SUSPENSION BRIDGE.

Suspension Bridges and Ferries.

We manufacture wire cables and fittings expressly for suspension bridges, Fig. 138, and are prepared to furnish complete equipments if desired, and also competent engineers to superintend their construction. Applications for estimates should state length of span between towers, width of roadway, character of traffic and maximum load. They should, if possible, be accompanied by a profile on the center line of the proposed structure, which line should extend back far enough to determine the location of the anchorages. The profile should show high and low water and the kind of material composing the banks and bed of the stream.

Travel in many places does not warrant the construction of a bridge, and in these instances the wire rope ferry is found to be the cheapest and most convenient mode of passage. We make trolleys for running on the rope, Figs. 139 and 140, which are commonly known as ferry blocks.

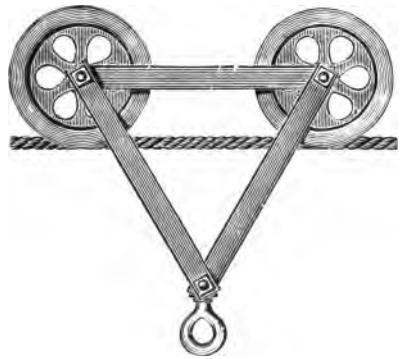


Fig. 139.

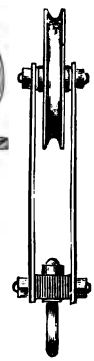
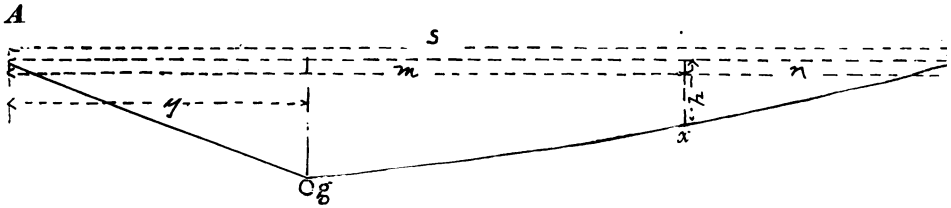


Fig. 140.

The general formulæ on the following page will be found useful in determining the deflections corresponding to a given tension at all points of a suspended cable, either loaded or unloaded, as the case may be, and also the tension corresponding to given deflections.

GENERAL FORMULÆ FOR ESTIMATING THE DEFLECTION OF A WIRE ROPE CORRESPONDING TO A GIVEN TENSION.



Let s = the distance between supports or Span $A\ B$;
m & n = the arms into which the span is divided by a vertical through the required point of deflection, x, m representing the arm corresponding to the loaded side;
y = the horizontal distance from load to point of support corresponding with m;
w = the weight of the rope per foot;
g = the load;
t = the tension;
and h = the required deflection at any point x;
all measures being in feet and pounds.

Then for

DEFLECTION DUE TO ROPE ALONE,

$$h = \frac{m\ n\ w}{2t} \text{ at } x, \text{ or } \frac{w\ s^2}{8t} \text{ at center of span.}$$

For

DEFLECTION DUE TO LOAD ALONE,

$$h = \frac{g\ n\ y}{t\ s} \text{ at } x, \text{ or } \frac{g\ y}{2t} \text{ at center of span.}$$

$$\text{If } y = \tfrac{1}{2}s,\ h = \frac{g\ n}{2t} \text{ at } x, \text{ or } \frac{g\ s}{4t} \text{ at center of span.}$$

$$\text{If } y = m,\ h = \frac{g\ m\ n}{t\ s} \text{ at } x, \text{ or } \frac{g\ s}{4t} \text{ at center of span.}$$

For

TOTAL DEFLECTION,

$$h = \frac{w\ m\ n\ s + 2\ g\ n\ y}{2ts} \text{ at } x, \text{ or } \frac{w\ s^2 + 4gy}{8t} \text{ at center of span.}$$

$$\text{If } y = \tfrac{1}{2}s,\ h = \frac{w\ m\ n + g\ n}{2t} \text{ at } x, \text{ or } \frac{w\ s^2 + 2gs}{8t} \text{ at center of span.}$$

$$\text{If } y = m,\ h = \frac{w\ m\ n\ s + 2gm\ n}{2ts} \text{ at } x, \text{ or } \frac{w\ s^2 + 2gs}{8t} \text{ at center of span.}$$

Note.—*If the tension is required for a given deflection, transpose* t *and* h *in above formulæ.*

ABRAM S. HEWITT, PRES'T,
PETER COOPER HEWITT, TREAS.
New York.

[redacted], MANAGING DIRECTOR.

WM. HEWITT, VICE-PRES'T,
E. HANSON, SEC'Y,
Trenton.

THE TRENTON IRON CO.,

TRENTON, NEW JERSEY.

COOPER, HEWITT & CO.,

17 BURLING SLIP, NEW YORK,

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